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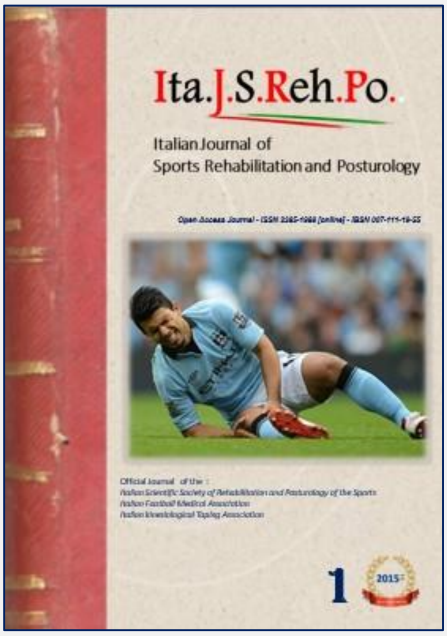


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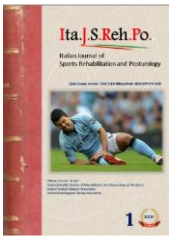

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# Diagonals : Part one

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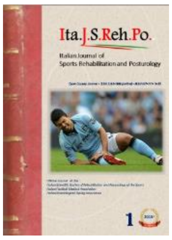
## Abstract.

Diagonals are muscle structures that support and help our bodies to move. In this article (part one) we explore the development of these diagonals from childhood, and the enhancement of them in professional athletes. Part two will then explore what happens when neurological diseases damage these muscle patterns. Neurological disease tend to affect how these diagonals work more than orthopedic diseases. This is due to a dependency on various structures within the brain. Although these areas of the brain are not yet identified the interconnectedness of the spine and the large joints give us a clear picture that only one hemisphere controls them both. The overall distribution is unequal (between 90% and 10% split) but it is this amount of variation within the distribution which enables the diagonals to work in this way. (Jan van de Rakt, Steve McCarthy-Grunwald, Diagonals Part One Ita J Sports Reh Po 2015; 2; 1 ; 143 -166 ; *ISSN 2385-1988 [online] - IBSN 007-111-19-55)*



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## Introduction.

When you are lying on your abdomen and you lift your arms in the air, you will feel that it is impossible to do so without lifting your head. Then when your head and your arm have raised into this position, your legs will also start to lift. Equally when you lift just one arm when lying on your abdomen with your head raised then you will notice that the opposite leg begins to raises from the floor. We can deduce therefore, that by lifting either arm there is a stimulus which goes across the back muscle diagonally to the opposite leg. Conversely when you lay on your back and lift your right leg straight in to the air you will notice a similar response. Even before you lift the right leg, you will feel some movement in the left leg. That is because the left leg will try to stabilize the body's balance thus enabling the right leg to move. As a consequence of this you're left heel will be pushed in the floor. Prof. Nashner (1) from previous studies has identified, that when a person (figure 1) pulls on a handle, the body automatically compensates for this action by moving the muscles of the back and legs including the both calf muscles.

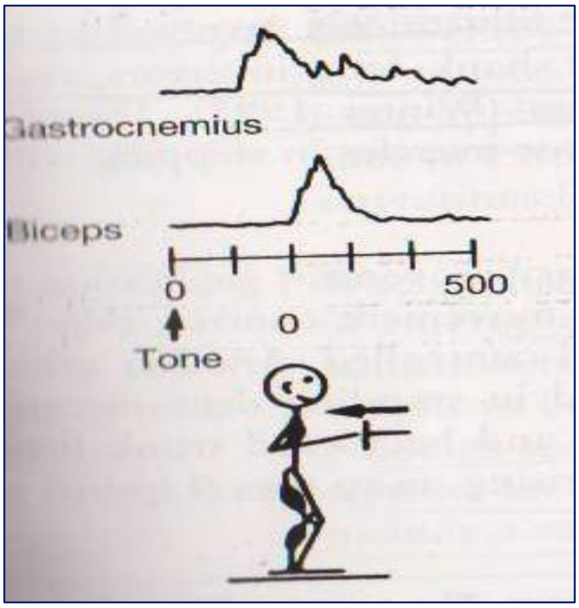


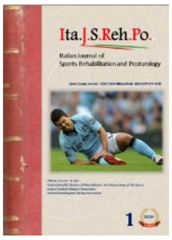

**Figure 1.**

Test from Dr. Nashner.

The person pulls on a lever. The first activation (EMG) we see, is in the m. gastronemicus before the person can physically pull the handle.

He person needs to have a level of muscular support to remain stable before any movement can be conducted by the arms.

When prof. Nashner asked the subject person to lift their left arm, they noted a muscular reaction in the subjects calf muscle on the on the opposite side. This reaction in the legs and back muscles is necessary to stabilize the body. Lifting or pulling movements therefore will alter the body's need to alter its position to maintain balance and stability.
The body therefore uses this diagonals system.

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## Diagonals

### *Back Diagonals*



The back diagonals are a pattern of muscles, that interact with each other to form a chain that start in either shoulder then travels down over to the opposite side to the buttock. Although a few muscles are directly connected with each other, not all muscles are and the remainder are indirectly connected.
Central to the back diagonals is the fascia thoraco lumbalis, this fascia lies directly on or over the back of the spine and has anchorage on either side of the pelvic border, on the vertebra of the lumbar spine and the sacrum.
When the aponeurosis is pull to the right the muscle on the left will react to counter the increased tension. This means that the muscle from the shoulder to the aponeurosis (M.Lattissimus dorsi) which pulls on the aponeurosis, will be counterbalanced by the gluteus maximus muscle.
This connection is at the base of the back diagonals.
The alignment of this diagonal must be at an angle of 45 degrees (figure 2), which is the best and most effective position to be in along with other structures such as the front diagonals and the homolaterale structure.
A 45 degrees angle allows the buttock to perform at its optimum functional capacity. We will observe in part 2 that this muscle is also the weakest part of the back diagonal.

### *Front Diagonals*

The starting points are in the shoulders and the hip joint, although unlike the back diagonal the aponeurosis is not equal at the front. Therefore the rectus abdomen muscle must perform this function. As a result it ability to perform equal to the aponeurosis thoraco lumbalis, will vary depending on the tone of the abdominal muscle wall, and thus allow for this stability. Within this diagonal the internal and external stomach muscles are the main muscle structure which start and terminate about 75% into the rectus abdomen. This means that any pull from the muscles on the right must be countered by the muscles on the left. The front diagonal does not have a single muscle which goes from the rectus to the shoulder or the hip. Therefore cooperation between a series of muscles is required to enable the front diagonal to function. The cooperation between a series of muscles, enables the front diagonal can do his job (Figure 3).
Therefore when we elevate our arm in anteflexion, the scapula is required to move otherwise it is impossible to get the shoulder joint to move forward. This movement is performed by the m.seratus anterior, which itself requires a stable ribcage to perform this movement.
This stabilization is achieved by the m. abdomen externus on the side being elevated with the m.abdomen internus on the opposite side. This in turn requires a stabile m.rectus abdomen and m.transversus abdomen.

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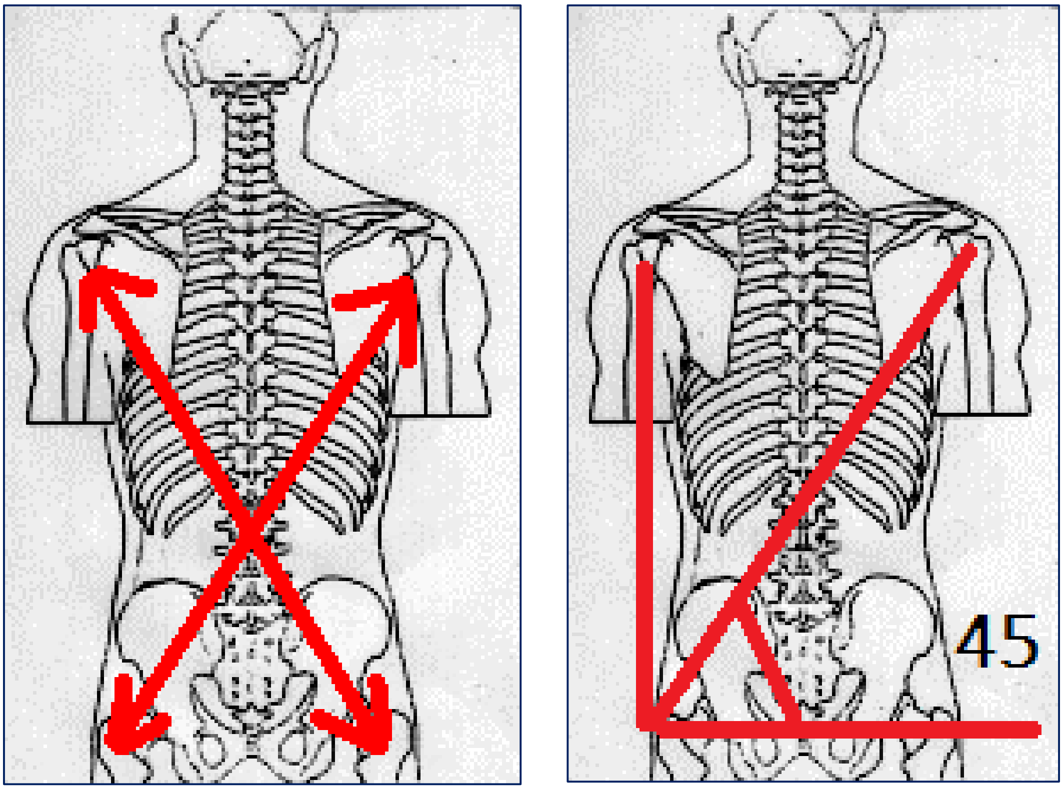


**Figure 2**.

The back diagonals.

They start at the trochanter major and goes through the buttock, fascia thoraco lumbalis over to the other side and terminates in the shoulder joint.

The perfect angle for the diagonal to work is at 45 degree. When this angle is altered than there will be reduced function in the diagonal especially in the hip region.

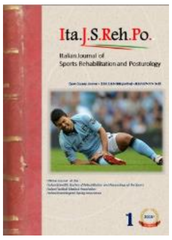

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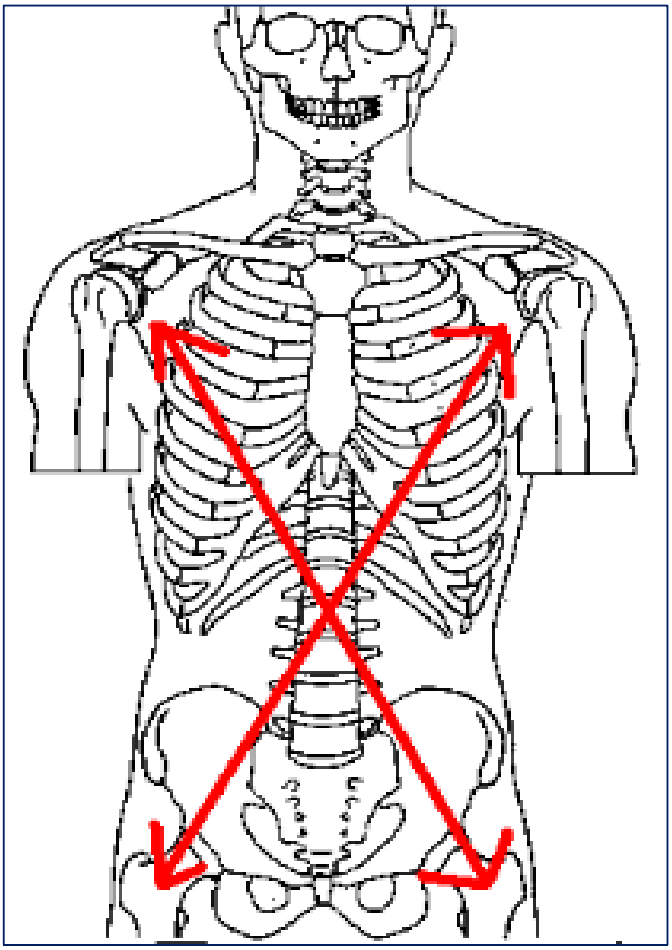
**Figure 3.** The front diagonals.

The starting point is the insertion of the m.iliospoas on the collum of the femur and run through the abdomen to the opposite shoulder.



The connection with the hip joint on the opposite side is also different when compared with the back diagonal. The back diagonal has a direct attachment by the aponeurosis through the m.gluteus maximus, whereas the front diagonal has no direct connection with the hip. The hip muscles are attached to the pelvis, the lumbar spine and the column of the femur. To function efficiently it is extremely important that the pelvis is remains stable. Therefore the stomach muscles in combination with the back and buttock muscles must work together to provide this stability. This enables the hip flexor to function correctly.

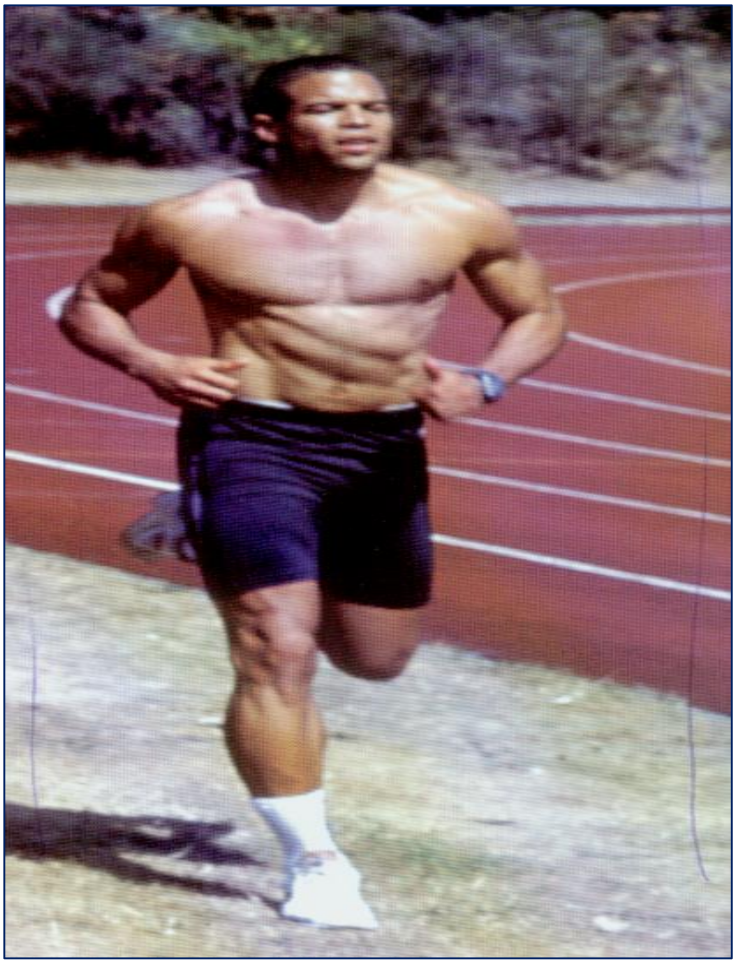


**Photo 1.**

This photo provides a good example of the front diagonal in action.
You can clearly see the structures on his stomach which increase the tone allowing him to swing his left leg forward.

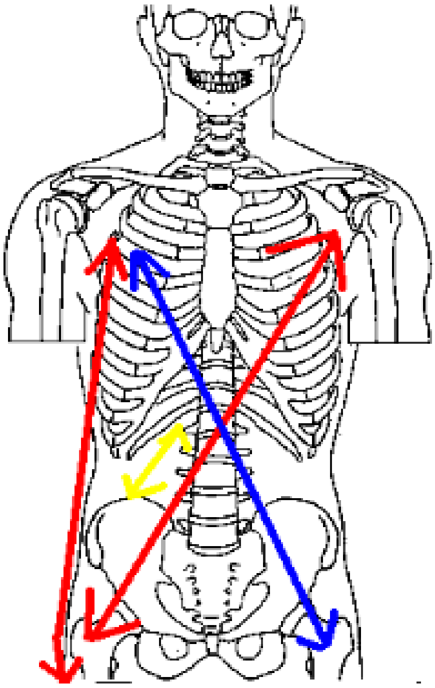
Observe how it runs from the left leg over to the right shoulder.

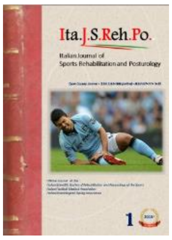
**Photo 1**. Here you can see how the front diagonal “walks” over the stomach.

## The homolateral muscle pattern.

The body has more than just these back and front diagonals. There is also an overlap at both the key points of both the shoulders and hips. Here the front and back diagonals converge and creates a further differentiation (Photo 5) within the form and function of the muscles. We can observe this mainly in the great muscles, but also in function of many lesser muscles that are present at these key points. This homolateral muscle pattern is not only important in sideways movement, it also has a key role in body rotation. (Figure 4a & 4b)

**Figure 4b.** Combination of front, back (yellow) and homolateral muscle structure. The muscle structure is very similar to that of figure 4a. as it goes through the entire hip, trunk and shoulder.





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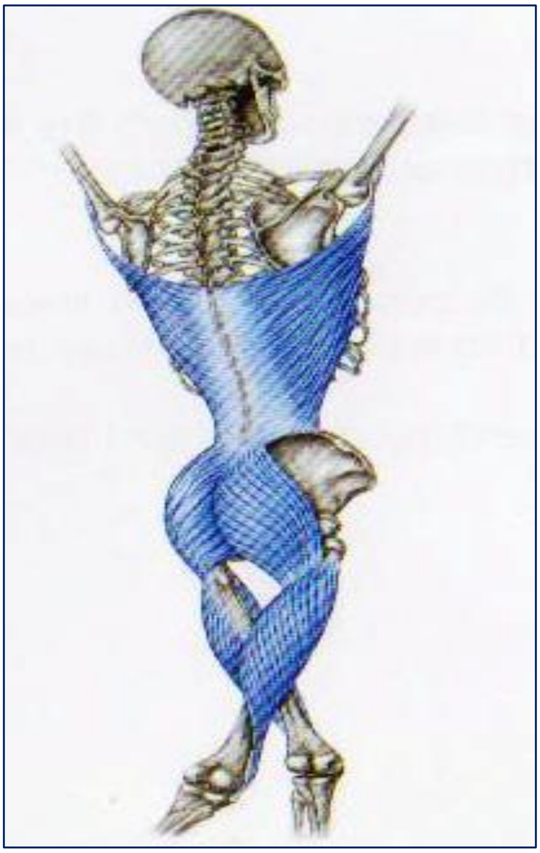

**Figure 4a.**

## Development of the Diagonals.

As Children develop the ability to walk upright (upright attitude) they are required to build and develop these muscle patterns over time. This is somewhat unrefined initially but with practice of the movements the muscle systems adapt toward becoming fully functional. We see this unrefined pattern by children when they start learning to walk. The greatest problem is balancing on one foot. To achieve this, all joints are required to become stable enabling only one joint to move freely. There must be only one joint move and all other must be stabilize (Photos 4 & 5). Children achieve this by using co-contraction in all joints and allow only one hip to move. (Photos 2, 3 & 4)

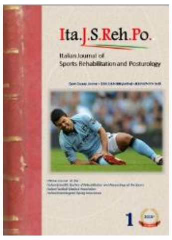


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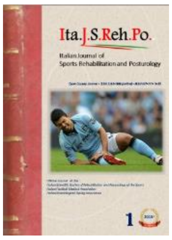
**Photo 2, 3 & 4**

My three grandchildren are learning to walk. What we see is the high tone of the upper trunk and arms with a lot of abduction.

Now they are able to balance and walk without falling after each step.

The hip of the standing leg moves forward a little and the trunk move sideways over the hip. This allows an endorotation in the standing leg. This in turn makes it possible to move over the standing hip and at the same time move the other leg forward.
The stability of the trunk comes from the back diagonals initially, although this movement is only possible when the trunk is stabilized. This stability is achieved by increased tone throughout the arms. The arms are in abduction and exorotation, often in a 90 degree angle from the shoulder.







This enables the upper trunk to be totally stable and as a consequence a movement to the lateral side in the hip is not required, because the upper trunk makes this movement, called a Duchenne movement. At this point the action of the buttock muscles are not required and the hip can now be extended by using the adductor muscle. (Note: The angle of the back diagonal is now greater than 45 degrees).
With exercise, the hip muscles will further develop resulting in an increase of step length, more sideways movement in the hip, reduced movement of the upper trunk sideways and a decrease in tone of the upper trunk.
We can also observe that when the child has its arms down, by their sides with their elbows in flexion, this is a sign that the tone remains high to maintain balance.
Development of the muscle pattern starts with a co-contraction of the back and the front diagonals. The back diagonals enable the upper trunk to remain rigid whilst allowing one of the hips to move. The opposite leg therefore requires no front diagonal to be able to swing freely.
Rotation in the trunk is not present during this movement. The rotation makes the child in the hip and that movement is an endorotation. The next step involves rotation in the spine together with the hip and reduction of tone in the trunk. Resulting in a left leg extension along with the right arm, and the right leg swinging together with the left arm whilst the person is in an upright position.
The homolateral muscle pattern completes the movement of the diagonals. The key points – (shoulders and hips) - a muscle structure which allows us, to balance on one foot whilst adjusting our position moving over the hip and simultaneously swing the opposite leg forward.

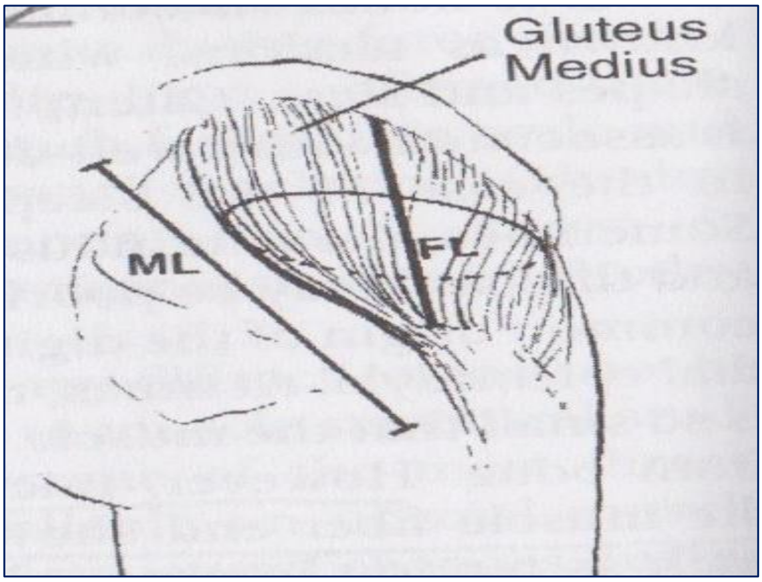



**Photo 5.**

**Photo 5.**

Dr. Lieber identifies, that the muscles especially round the key point (the hips) have a different fibrous structure that makes it possible to move over the hip with lateral stability.

## Normal function.

The back and front diagonals provide the basic structure for all our movement. There will always need to be a cooperation between the front and the back diagonals, and between the two individual back diagonal and the two individual front diagonal. Furthermore any movement which goes from an antagonist to agonist function will always take place in these key point joints. When we turn over in bed to lay on one side the opposite leg will move and in turn requires the leg touching the bed to adjust compensating for this movement. When we move the upper leg forward we must adjust the upper shoulder backwards, together with the leg closest to the bed creating an active exorotation and fixate the foot and leg to compensate for the movement. We require the back diagonal action to enable us to lay in bed on our side and then to move the opposite leg.
The same is observed when we lay on our back and raise one leg. Before the leg raises the back diagonals have to adopt a position to stabilize the body making it possible to perform this movement. It also occurs when we lift the head or any part of the upper trunk to turn to the left. The right leg stabilizes the body and makes the movement possible.
We can observe the diagonals best when we are walking, running or if we lose our balance, which are all basic essential movements for independence

### Walking

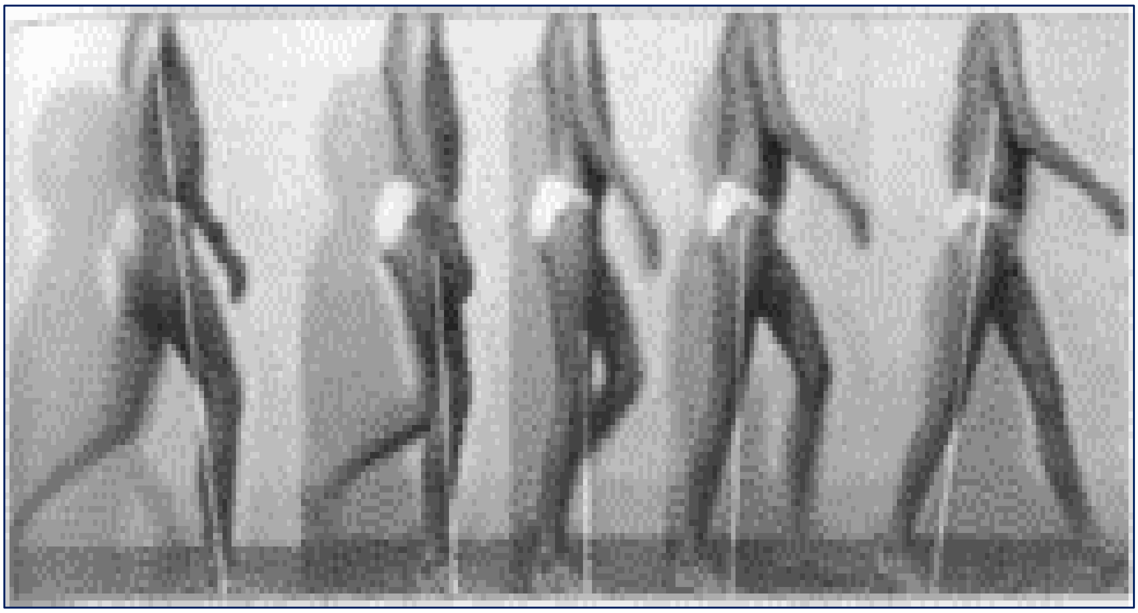


**Photo 6.**

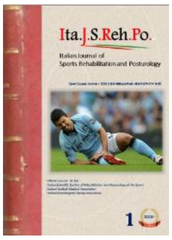


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**Photo 6 Walking pattern**.

1. Right midstance and left start with the swing. The arm are partially in front of the upper leg, the other arm is still behind the trochanter.

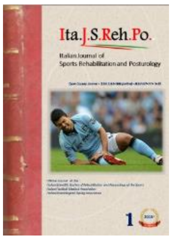
2. The left foot is starting with the swing phase and the right arm is now in front of the trochanter .The right leg is in midstance and the left arm is not visible

3. The left leg is now in front of the right leg, but still in swing phase. We now see the right arm also in front and almost perfectly parallel. The right leg is at the end of the midstance and we cannot see the left arm.

4. The left leg has almost reached the moment that the heel strike occurs and we see that the right arm goes further forward with a slight movement of the wrist. Right leg and left arm almost the same as with stage 3

5. The left leg is now on at the floor but not in a weight bearing position and the right arm is at the end of the swing phase and the wrist is in a neutral position. The right leg is starting the push-off phase and now we see that the left arm is appearing behind the back and moving backward.

Walking gives us a picture into which the diagonals are clearly present. The movement of the arm and the opposing leg are similar. And when in the swing- and stand phases and this is repeated every time, increasing or decreasing in speed and rhythm whenever you move faster or slower. To enable the movement of arm and opposite leg in symmetry whilst walking requires the hip to be able to rotate with the movement.-Therefore at the beginning of the stand phase there is an exorotation in the hip joint followed by an (endorotation) at the end of the stand phase. To allow the rotation of the hip there needs to be (a degree) of compensation by the spine. Photo 8 (shows this compensation in action.) Observe that the right hip is in maximal exorotation and flexion and the left arm is towards the front with a rotation of the upper trunk forwards (this action involves the front diagonal). The left leg is at its maximal extension and endorotation, together with the right arm in retroflexion and the upper trunk moves in a backward rotation (this action involves the back diagonal). Therefore a rotation in the spine on thoracal 11 and lower is required.








## Running

Once there is a difference in position between the left and right sides of the body you can see, that the diagonals begin to assist each other. In photo 8 the subject has an arm swing on the left side which is significantly higher than what is usual for the swing phase when running. The reason for this is that the right leg does not have the right amount of power in the swing phase to get to the front at the right time. As a consequence the front diagonal has to makes an adjustment to compensate for this.
Therefore the tone and the length of the front diagonal is increased by boosting the speed of movement and the height of elevation for the left arm as it moves forward, enabling the right leg to move at the correct time.
We can especially see this with individuals doing sport, when performing at their maximal capacity the diagonals not only have to adjust in the arms and legs but also within the wrists and the ankles to achieve the same movement.
This results in the entire diagonals having to be used to maximize the performance (Photo 9).


**Photo 9.**

Here are five subjects running the 100 meters, with each person in a different phase of movement. *Runner 891*, is in the push off phase with the right leg and we see that her wrist had adopted the same position. *Runner 890*, is in the fly phase and the right leg and foot is preparing to land and is currently in a midstance position, observe how the left wrist is in the exact same position. *Runner 889*, also in the fly phase but is slightly further along the sequence of running than Runner 890. We can see the start of the dorsal flexion in the left foot and also in the right wrist. There is also rotation in the spine between the left hip and right shoulder, this is also visible on the muscles of the abdomen. With the umbilicus located perfectly in a central position. We can also observe that the right arm is pushed forward to encourage the left leg to move forward more. *Runner 888* has the right foot in a standing position with the foot flat on the floor. It is going into the pushing-off phase and we see that the left wrist is going into palmair flexion. *Runner 887*, fly the right leg is totally straight with slight inversion in the foot. The foot is required to move more towards a dorsal flexion and we can already see this in the left wrist
In sport situations when people are functioning at the ultimate level, we can see that the diagonal goes not only from shoulders to hips, but goes all the way to the individual’s feet and the hands.

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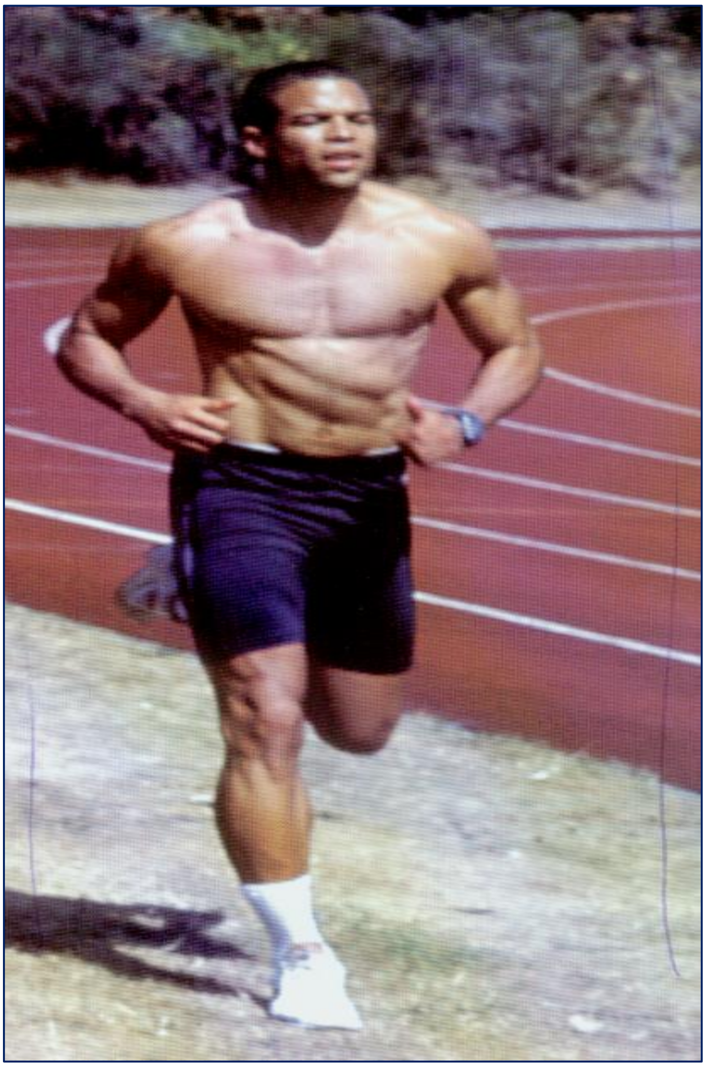
As a consequence, injuries must be treated not only where the damage is, but also across the entire diagonal system. This is referred to as Task Specific Resistance Training (6)



**Photos 7 and 8.** It is useful to note how you can observe how perfect the abdominal muscle function is by the position of the umbilicus. This identifies that the abdomen muscles must work together to enable the perfect swing and overall stability of the entire body.


**Photo 8.**

## Baseball

An alternative sports situation is Baseball. Here the arms are the instrument that lead the movement. When we are performing a throwing, catching or hitting type movement the arms are very active and require the legs to provide maximum support. When hitting the ball with a bat, the resulting movement requires the front diagonal to shortening. This creates a fast close shortening chain with which to strike the ball with significant force. Individuals that are either throwing or hitting, or the pitcher and the batter stand opposite each other but at a 90 degree angle instead of being face to face. Why?
When we are looking to hit or throw a ball with significant force, we need to expand the front diagonal as much as possible. Additionally it also needs to be in an elongated position. Therefore by standing with the side of the body towards the other person enables the front diagonal to become elongation with an extra rotation. That elongation together with the rotation makes it possible for more power to be generated and as a result the person can either throw or hit the ball much harder and with more precision. When the front diagonal is able to shorten quicker, then it is very important that one end of the diagonal has a fixed point. Thus one foot must remain on the ground to enable the diagonal to remain short and move quicker.

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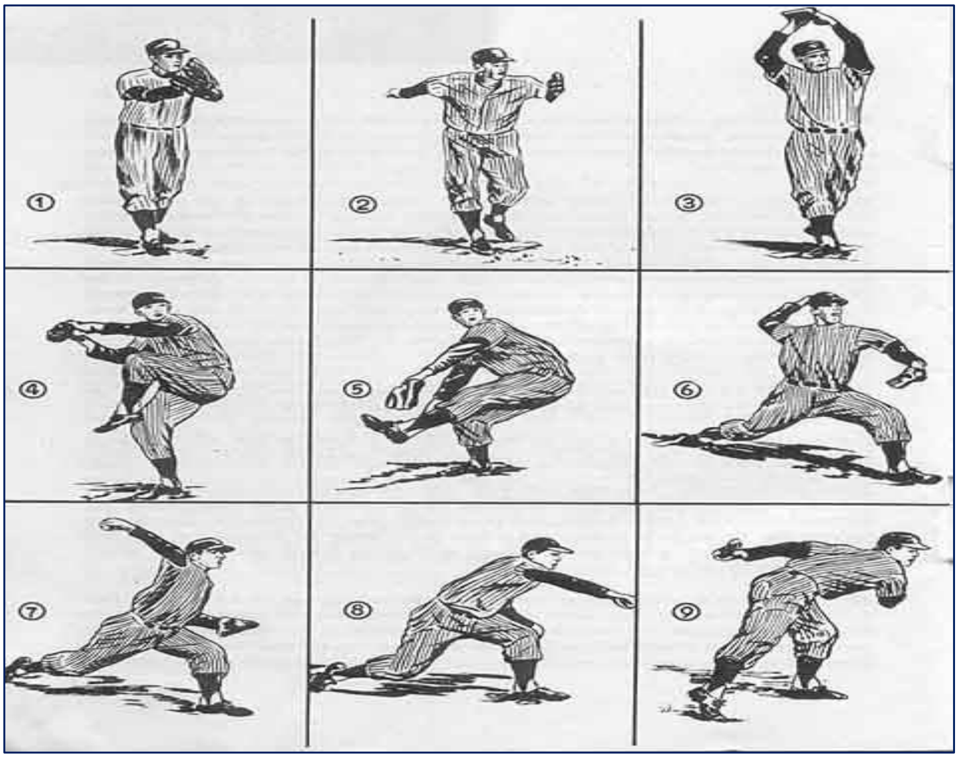

**Photo 10.**

Starting with picture 4, we can see the shortening of the diagonal. The person is now getting more tone in the front diagonal.

The pitcher starts the throwing movement by stretching out the left leg which helps to elongate the front diagonal. Raising and holding their leg in the air helps to maintain an increased tone and size in the front diagonals. In picture 6 the front diagonal is at its longest position possible. The left leg is standing towards the front of the body and the right arm is extended backwards behind the body.

The position of the arm in the shoulder is achieved because the back diagonal allows the shoulder blade and the glenohumeral joint to move. Therefore a maximum amount of exorotation, with 90 degree abduction and retroflexion against the border of the joint, and 90 degree flexion of the elbow.

Now the front diagonal is shortening and that process is started by the left foot. The whole body moves over towards the left foot and that creates an increase in speed. Finally comes the arm with a lot of endorotation and extension of the elbow.

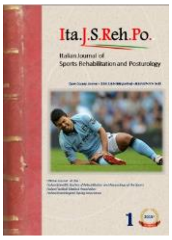


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**Photo 11.**

Hitting the ball is a little bit different where the hand makes a closed chain. Now combined action of both the front and back diagonals will be required. Not only as agonist and antagonist, we now see the movement start with the front diagonal as agonist but due to an increased amount of rotation, the movement will need to be finished by the back diagonal as agonist. The reason for this is due to both arms having a closed chain, which means that the movement has to come from the trunk. Therefore the trunk rotates and the arms swing with the baseball bat. To perform this we require a fixation to enable the movement to take place. Photo 11 shows how the movement starts in the left leg, but as the baseball bat move beyond the right leg then the fixation transfers to this leg as a consequence

Start with the hit:
The person has the baseball bat behind them and will start with a shortening of the back diagonal from the right leg/foot to the left arm.
Then when the baseball bat has swung to the front of the body, the remainder of this swinging movement will be done by the front diagonal of the left leg and right arm. Photo 11 gives the moment that this will happen.
The closed chain movement of the arms on the bat give the body no other option as to move with legs ~~as~~ in fixation.

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## Football

Kicking a football requires a different type of cooperation as previously seen, which is between both the diagonals and the homolateral structure to get both the best performance and the best results. The variations are numerable but often the rule is one leg/foot takes care of the fixation required whilst the other swings to kick the ball.



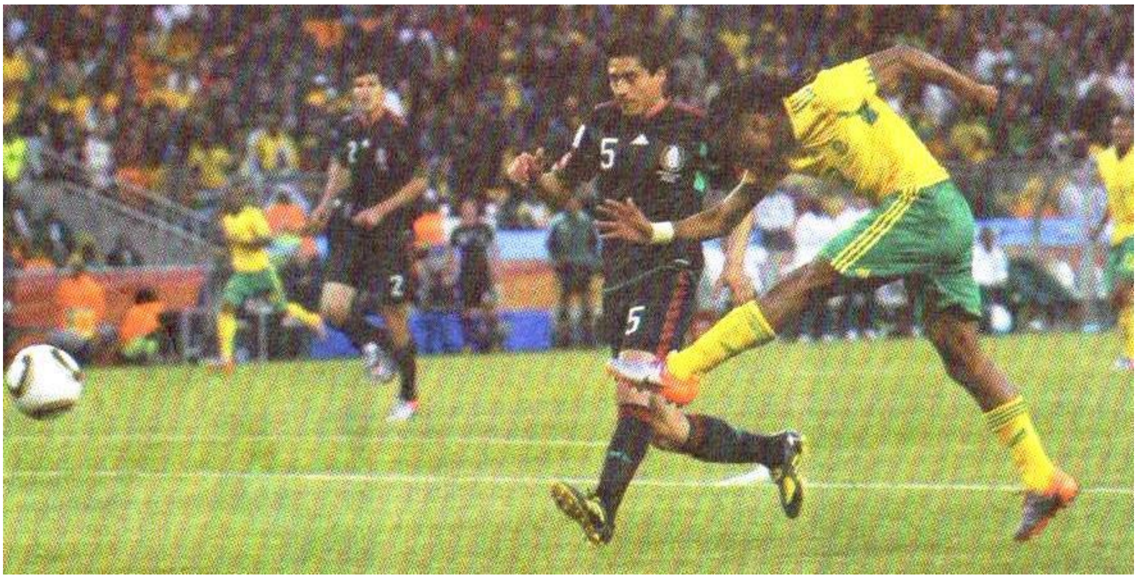

**Photo 12.**

The footballer (photo 12) tries to hit the ball as hard as possible with his left foot. This action comes from the front diagonal, and we can see the extent of this movement all the way to the position adopted by the right arm. In his right hand we can see extension in the fingers, which enable the player to hit the ball with more accuracy and precision. Observe how the right leg having performed a jump enables the player to get closer to the ball. We can also see within left arm the amount of power that is evoked in the back diagonal.

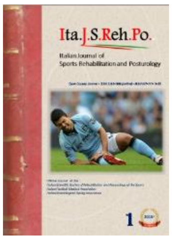

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**Photo 13**

The control over the ball with his foot requires one foot to stand still on 0 degree dorsal flexion.

Observe what the left wrist is doing.

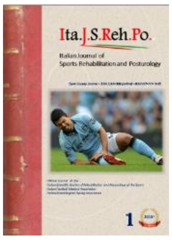
**Photo 13.**

## Skating

Skating, our national sport, requires a firm outlet of one leg. But the fixation is very slippery, so how do the diagonal enable that?

**Photo 14.**

When the outlet is passed, the left leg is not on the ice, but we can still see that the last part of the movement was a plantair flexion of the foot.



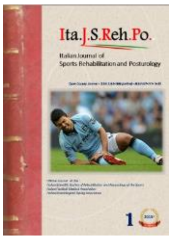


Observe how the right wrist, has moved outwards with this plantair flexion to create a dorsal flexion helping to lift the foot.
Why do many skaters hold their arms behind their back?
The reason for this is that they create a closed chain which helps to stabilize the upper trunk making it easier to hold the trunk at a 90 degree hip flexion position allowing the legs to do their job. Children can also be seen to adopt this position when learning to walk. We can also observe this with older people who have some evidence of balance deficits.
One of the most beautiful picture I have ever seen involves athletes that are racing in the 110 hurdles.

## Hurdles run


**Photo 15.**

Being able to maintain the velocity whilst jumping over the hurdles requires a lot of specific movements. They must kick their lead leg/foot out towards the hurdle, which results in this leg being straight with increased flexion in the hip.
The other leg is required to move outwards which in itself requires great mobility and muscle control to achieve the position.
This picture shows perfectly the dorsal flexion of the right foot and the dorsal flexion of the wrist of the left arm and the extension of the knee and the elbow. Even the hip and the shoulder make the same movement. This front diagonal is very short with high concentric contraction of the muscles which means that the back diagonal of the right leg to the left arm are elongated. The opposite leg has to be extended from the hip with the foot in dorsal flexion and we can also see the right arm is standing in retro flexion with the wrist in dorsal flexion. The left leg must now move into abduction which will also be mirrored in the right arm.



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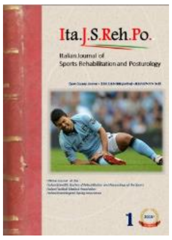
We can see here in just the one picture a concentric contraction of one front diagonal and concentric contraction of one back diagonal, which is extremely difficult as all diagonals must work together to performance best.
The power of the arms are necessary to get the front and back diagonals to function at such a high level. Less power in the arms, shoulders, elbows and wrists make the front diagonals power reduced when performing shortened tasks. The velocity of the retroflexion or the anteflexion must be equal with the velocity of the legs. This is because both the legs and the arms need to move in synchronicity to enable the shortening of the front-and back diagonals, and therefore increase the power and speed they are working at.

## Balance

Normally we would not be able to see the diagonals in such extreme detail as in these pictures from different sports. We would only expect to see the diagonals in the larger joint key points, rather than in the extending to the feet and wrists too.
There is however one exception and that is when we lose our balance.
Balance requires a quick and strong reaction to brace the falling movement and create a moment of time to enable one foot to be free. Then we are able to restore our balance by placing this foot forward, backward or at any junction between these two points.
The brace reaction requires an immediate response. Therefore we would use our diagonals to perform this.
When we fall forwards, the back diagonals act as inhibitors making an extension in the hip and trunk, so that the legs are stretching all the way to the feet whilst the arms go in retroflexion also with full extension. When there is a need for a quick and immediate response we would see reactions in both the wrists and the ankles too.
Balance training can only be successful once the brace power is restore.
That requires the entire diagonals otherwise this brace will not be achieved quick enough resulting in not enough time to place the opposite leg in a position to create a stable base.





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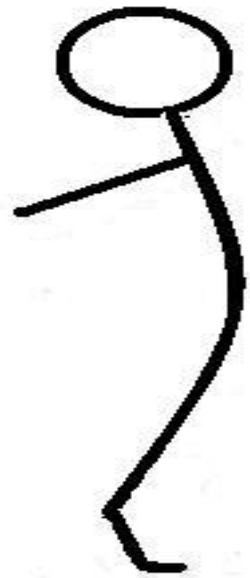


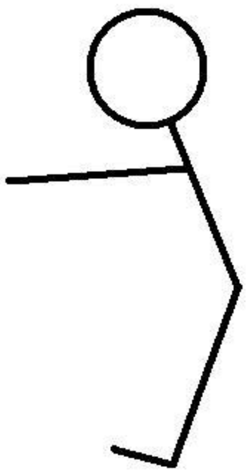
## Figure 5

The brace movement of the body following a push from behind.

This involves a reaction from the entire back diagonals.

Of course this depends on the amount of force in the push itself.

With a small amount of force we would see only a minor reaction which is often only a small step to the front.



## Figure 6

When pushed from the front we now see the action of the front diagonals to brace against falling. With significant force this movement involves the whole body to prevent you falling over. Therefore the arms and the feet are move both quickly and simultaneously with a flexion of the hips and trunk.

This brace is necessary to provide enough time to place the weight on one foot and to lift the other foot and to step backwards.

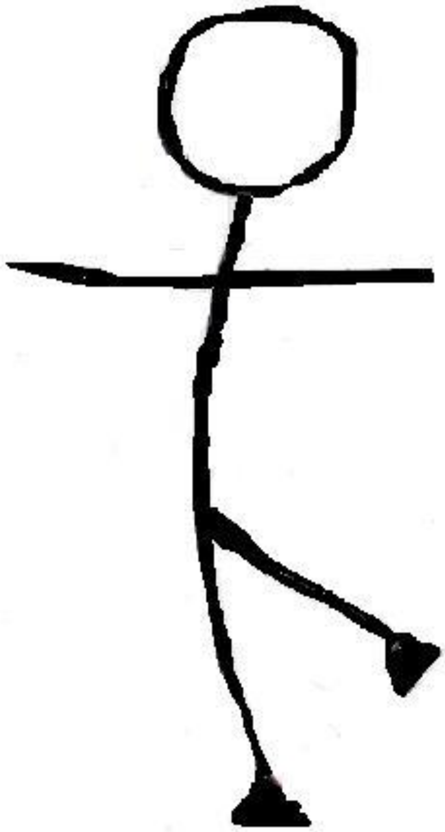
**Figure 7**

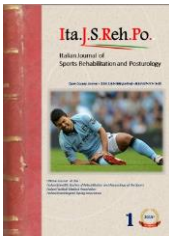
This happens when we lose our balance in a sideways movement

Here the homolateral structure plays the primary role and requires the ability of the trunk to react and brace first.

Later on, if required, we see a reaction in the ankles with an inversion movement.

The brace is followed by a sideways step and that can be in either of two directions. Forwards or backwards from the standing leg, backward requires part of the back diagonal and forward requires part of the front diagonal.










## End of Part one

In part two we will discuss what’s happen with the diagonals when people are suffering from neurological conditions.

## Reference

In the last part of the article.

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