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Fa jin and Extraordinary Power Amplification in Chinese Martial Arts

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Abstract

We explore the evidence that several animal species are able to utilize elastic power that exceeds several times the capacity of their muscles. These powers are generated from a store and release system like an elastic catapult. Some species utilise an anatomical feature as a catch in the store phase, but vertebrates do not have such anatomical catch. It has been suggested that they can utilise non-anatomical dynamic catches in the storage phase. We suggest that such mechanism implemented in the *kua* are indeed the source of internal power in Chinese martial arts.

Introduction

There is a fascination fanned by media and movies about the hidden secrets in traditional Chinese martial arts (CMA). The supposedly secrets ranged from the ridiculous fatal one touch kill to gravity-defying *qinggong*. In this article we want to propose a bio-mechanical mechanism for explosive power discharge, also known as *fa jin*. We begin by reviewing animal physiological studies and extrapolating it as a feasible human mechanism.

Fa jin is said to be a distinctive characteristic of Chinese internal martial arts such as *Taijiquan*. It is a striking method that is characterised by an explosive power discharge that is (supposedly) different from ordinary strikes or punches. We will examine how is it different in this article. It is commonly believed that the power is generating in the *dantian* - usually identified to be the muscle groups the vicinity of the waist and abdomen. In videos of *fa jin* by senior practitioners of Chen *Taiji*, a *fa jin* has a discernible feel about it[a], in particular a visible recoil or vibration is visible the end of the strike. This visible difference is what separates it from a normal punch or strike.

Some explained that *fa jin* as an alignment of body that generate maximum torque (Guillete, 2010). Others believe *fa jin* is a whip like movement that accelerates

[a] Chen Xiao Wang demonstrating *Fajin*. https://www.youtube.com/watch?v=5LosS2vjmek Accessed: 23 April 2020.

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from a relaxed state. It has also been characterized as a turning of the torso at the waist-groin junction (Ong, 2017) that is somewhat alike a golf swing. It is also mentioned that these torque actions require the participation of deep muscles, particularly those at the sacral iliac joint and hip-joints. And they must align with the core axial muscles of the vertebral column, otherwise any misalignment would impair power output. However, these explanations as optimized strike can also found in boxing manuals (e.g. Dempsey, 1950). If these explanations are accepted, then *fa jin* is not something extraordinary but a streamlined physical motion that any well-trained athletic will know how to execute. If this is true, then no further exposition is needed.

There are also some other explanations of *fa jin* have no scientific basis, glossing over science terms with incoherent or unexplained mechanism. In this paper, we will ignore esoteric claims. We hope to provide a more plausible scientific explanation. Once the science is better understood, hopefully the mechanism can be easily reproduced, shared, and practised in a more widespread manner.

Elastic Ballistic Power in Animal Species

It well known that skeletal muscles provide mechanical energy for movement. However, it has been observed that in certain species the power output does not match the muscular power capacity. It is believed that the utilization of a catapult-liked mechanism in the muscle tendon unit system makes it possible for muscle tendon unit to exceed the power limits of muscles alone. This is an example of power enhancement found in the animal kingdom.

Frog jumping provides an ideal system to study relation between muscle capacity and locomotor performance. Research results indicate that the difference in jump power (w/kg) is not matched by the available muscle power. The available muscle power is measured by the peak power of individual muscles (Roberts et al., 2011). The difference measured could be between 3 to 7 times of the muscle power (Roberts et al., 2011; Sawicki et al., 2015). It has been noted that Cuban Tree Frogs have a measured jump power of 1,047 w/kg while their muscular power is measured at 327 w/kg. This is three times more than the measured pure muscle power (Peplowski & Marsh, 1997). This indicates that their jump performance is not solely dependent on the muscle power.

Other studies have also shown that there is no correlation between muscle mass and jump power. This is because the observed power output exceeds the power producing capacity of muscles. This suggests that some non-muscular mechanics are involved. The observation that peak power output during a jump exceeds available muscle power provides evidence that there is another mechanism that serves to amplify muscle power output. The discrepancy between muscle power and peak power during a jump may be explained by the storage and recovery of muscle work in elastic structures. Evidence for elastic power amplification have not only been observed in frogs but also in mammals, birds, salamanders and chameleon (Sawicki et al., 2015) as well. Toads, salamanders and chameleons use elastic power amplification to rapidly extend their tongues during feeding (Roberts & Azizi, 2011).

The difference in the observed power output over power producing capacity of muscles is used as an indicator and evidence of elastic power. Elastic energy storage enables a wide range of animals to produce prodigious amount of power that is more than what their muscles can provide. Such single shot high ballistic power is often used in prey catching.

While the spring-like properties of tendon amplify of muscle power during jumping and acceleration, it also functions as power attenuating protective mechanism (Konow et al., 2012).

Tendons as elastic structures can provide the source of elasticity for ballistic movements. The tendon elastic properties can be used in amplification of muscle power for activities like jumping. In frogs, the power is stored in elastic structures in the pre-release phase then it is released rapidly during the take-off phase. Measurements using sonomicrometer measurement support the idea of elastic pre-storage. Tendon stretch is always followed by elastic recoil releasing 80-90% of energy stored. During power movements, the tendon act as springs that store work done by muscles then releasing rapidly (Sawicki et al., 2015) in recoil. When the energy is released more rapidly than it is stored, the power output would be amplified. Elastic recoil acts like a catapult action.

In human studies it has been noted that in human jumping, the force exerted by long contractile muscle is transmitted to the bony attachments via tendons (Bobbert, 1986). Note that this is, however, different from spring-like bouncing in human walking (Ishikawa et al., 2005). This indicates that a similar spring recoil system is available to humans as well.

The catapult-like movement leads naturally to a two-phase action understanding of the muscle-tendon system: (1) the loading or storage phase and (2) the release phase. During the initial loading or storage phase, the elastic structure must be held in place before the recoil can be released. In some animals there is a latch or catch that prevent the appendage from moving before the muscle is fully contracted. When the catch is released, the stored energy in the elastic structure would be released very quickly thereby generating higher power. Recoil occurs ballistically after release of catch mechanism. If you imagine that such elastic structures as a catapult-like system, then it will have a catch mechanism to store energy prior to the release of movement. The catch mechanism enables the muscle to initially shorten and contract, stretching the elastic structures and tendons. When the catch is released, the elastic structure recoils and rapidly releasing stored energy in a short period of time.

Some animals like stoma pods (mantis shrimp) uses a specialized exoskeletal spring mechanism (Patek et al., 2004; Patek et al., 2011). The mantis shrimp’s power amplification is derived from an extensor muscle that compresses a spring-like mechanism that is latched controlled by flexor muscles. The spring mechanism is arched like an archer’s bow (Patek et al., 2004). The catch or latch is like the trigger mechanism in a catapult that prevents motion before release. These catch mechanisms prevent joint motion and oppose muscle force to allow the elastic structures to be loaded. Many arthropods employ such anatomical catch mechanism (Gronenberg, 1996).

However, no such catch mechanism has been found for jumping vertebrates (Astley & Roberts, 2014) despite knowing that they employ similar power amplification methods. How does vertebrates load the elastic structure prior to movement if they lack such anatomical catch? An effective catch mechanism must allow elastic pre-loading such that it should resist motion before the release in the elastic recoil. Since it must resist early motion, an opposing mechanism must be employed that limits joint movement. As such, the opposing mechanism have act to limit joint movement. Systems without a catch mechanism have to create a transition from a low mechanical advantage position in the pre-loading to a high mechanical advantage just before the elastic recoil or release. Any mechanism that run counter to this pattern cannot function as a non-anatomical catch mechanism (Astley & Roberts 2014).

It has hypothesized that an inertial catch mechanism may be mediated by variable mechanical advantage to facilitate it. Astley & Roberts (2014) have investigated several mechanisms for anuran (frog species) jumping, such as gravitational load of the body, mechanical advantage and moments generated by proximal joints to create the initial elastic loading. They concluded that for the anuran species, jumping power amplification is mediated by proximal joint moments and variable mechanical advantage. They suggest that these functions as a dynamic catch mechanism that facilitates elastic energy storage and release.

It has been suggested that dynamic catches could also be implemented by antagonist muscle forces (Gronenberg, 1996), or dynamic changing lever ratios (Roberts and Marsh, 2003). Such dynamic catch mechanisms may provide an effective alternative to the anatomical catch and triggers systems observed in many invertebrates (Patek et al., 2011). Therefore, it is possible to do without an anatomical catch - the inertia of the load itself can be sufficient to allow tendon loading. In this case, the amplification would be load dependent. It has been suggested that non anatomical dynamic catches can be implemented through either of these mechanisms: local inertia, antagonist muscle, lever ratios or differential moments

Based on the above short review, it can be seen that elastic recoil power is quite common in the animal kingdom. Moreover, elastic tendon power can exceed muscle power capacity. Therefore, this method of generating extraordinary power is a good candidate for the internal power in traditional Chinese martial arts.

Analysis of Taijiquan Classics text

In *taijiquan* classical texts, strikes are often described as powerful and unceasing wave torrent that is strong like tempered steel, for example: (note: all quotations are from Davis (2004)):

> *Long Boxing is like the Long River and the Great Sea, an unceasing torrent. -- Taijiquan Jing*
>
> *Wield power like tempered steel, so strong there is nothing tough enough to stand up against it. – Wong Zongyue Treatise*

Move the jin like steel tempered a hundred times; what is so solid that it cannot be broken? One's appearance is like a falcon pouncing on a hare; one's spirit is like a cat catching a rat. Be still like a mountain; move like a great river. -- Exposition on the 13 Postures

There are various clear statements of using the body's elastic store for issuing power (below). It is likened to be drawing a bow, though it is probably more accurate to say catapult. Some argue that it is the fascia from the back and torso that is providing the elasticity. However, there is no evidence that the fascia is capable of such elastic power whereas elastic tendon-muscle system is common in the animal kingdom. Like a catapult, the elastic store must be compressed to store energy.

Store jin like drawing a bow; issue jin like shooting an arrow. In the bent seek the straight; store, then issue. ... -- Exposition of Insights into 13 Postures
Store power like drawing a bow. Issue power like loosing (sic) an arrow. -- Wang Zongyue Treatise
Within curving, seek to be straightening. Store and then issue. -- Wang Zongyue Treatise
Within curving, seek to be straightening. Store and then issue. To gather is to release, for there is no discontinuity between the two moments. -- Wang Zongyue Treatise
Contracting is gathering. Expanding is releasing. -- Wang Zongyue Treatise
Stillness refers to contracting. When contraction finishes, there will be expansion. When there is movement, everything moves. Movement refers to expanding. -- Wang Zongyue Treatise
The jin is stored in the curved, then there is a surplus. -- Exposition of Insights into 13 Postures

There is also mention of curves in the quotations above. This is because the storing motion includes a winding movement at the waist and at the *kua* in the pre-release loading phase. This is conjectured to be a part of the silk reeling movement.

The following quotation can be interpreted as adding a dynamic catch after the winding movement. The antagonist muscle creates the dynamic tension and contradictory power to train the catch and release muscles separately. The winding movement is a store before the release. For the store to be effective, an inertial 'catch' must be in place. This catch must be in the different direction of the release. Therefore, for a forward release, there must be a backward hold before release by the antagonist muscle. The 'break' is describing the release from the catch.

There is up, and therefore there is down; there is forward, and therefore there is backward; there is left, and therefore there is right. If one intends to move upward, then send the yi downward. If one wants to lift something up, then a "break" must be added. -- Taijiquan Jing

Locus of Power Amplification

In Taijiquan text there is general agreement that the locus of the *fa jin* power generation is at the *dantian* but it is never explained what the *dantian* is. It is roughly known to be around the waist and lower abdomen area. But it is never explicitly clear how the *dantian* effects the *fa jin*. There are ample descriptions in classical texts about the use of elastic store but there is no written material on how this elastic store may materialize and utilized.

Earlier we have discussed that possibility of muscle-tendons system with a catch mechanism can be used to generate extraordinary power. The hip and pelvic girdle is home to a large number of powerful muscles, tendons, and ligaments. This area is also called the *kua*. It is proposed that the elastic recoil power is generated in this area. A loose *kua* (meaning flexible) allows the elastic power to be wound up and held together by inertia (body weight) and released by the change in body weight. The body weight with the help of some additional antagonist muscles acts as a dynamic catch. The use of antagonist muscles as a dynamic catch may also be the reason why some Chinese martial arts practise dynamic tension. When the body weight and antagonist muscles are released, the body winds forward and the *fa jin* is released. There will be a change in height when the strike is released (Fig 1) because the weight is lifted. In Fig. 1 the change in stance and height can be seen clearly as the body weight is released and shifted to the other foot. The arrows show the *kua* or the hip joint. The first image shows the elastic loading stage as the *kua* is folded in to store the elastic power. The body is lowered down to allow the body inertia to mimic a dynamic catch. Antagonist muscles also hold the elastic store in place. The 3rd image shows the release. Note the complete opening of the *kua* joint after the release of the elastic power. The release is evocative of a catapult. It is important the lower body structures are kept immobile or else there will be a loss of energy transferred. The body is also noticeable higher at the release (even though the individual images are not totally aligned). A proper release will also affect the spine if the upper torso is relaxed.

Figure 1. Chen Xiao Wang demonstrating *fa jin*[b]

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[b] Chen Xiao Wang demonstrating *fa jin*. https://www.youtube.com/watch?v=5LosS2vjmek Accessed: 23 April 2020.

Conclusion

We have examined some of the research in elastic power generation in the animal kingdom. There are many species that can generate more power than their muscle capacity. Some species, especially invertebrates, uses an anatomical catch to pre-load the elastic power. Even though an anatomical catch is not generally found in vertebrates, they are found to be able to generate elastic power. In such cases a non-anatomical dynamic catch mechanism is used. Power amplification using a catapult-like elastic power is found throughout a wide variety of animal species and the power output from elastic power is usually several times more than muscles alone. So, based on the broad similarity of vertebrate musculoskeletal system, it is possible for humans to release power that is multiple times more than pure muscle alone using elastic power. The use of elastic power as *fa jin* is mentioned several times in classical *Taijiquan* text. We have suggested that the elastic power is derived by the catapult action of the *kua* using a dynamic catch. We may also conjecture that other suitable body parts may also exhibit elastic power and not limited to the *kua*. However, our conjecture is based on a literature review on animal studies and personal experience. Therefore, a more definitive conclusion may have to wait for detailed experimental tests in a laboratory setting. We hope that our conjecture will lead to further scientific investigations.

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