Understanding Nage Waza:
Fundamental underpinnings of successful technique

Written By:

Sensei Luke Schmidt

Ni Dan Candidate

13th November 2016

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"I am always doing that which I cannot do,

in order that I may learn how to do it."

- Pablo Picasso

During a coach's career, most would have wondered what makes a good or even great coach. Is it their ability to command the respect of their students, an innate charisma that attracts people to them and has their students hanging on their every word or having achieved great heights in a competition that gives the students something to aspire to? In part, all of these things could be true. Yet, I if one were to have all of these attributes accounted for that may not be enough. It could be argued that above all these qualities, what makes a great coach is how they answer a seemingly simple question, that is, 'Why do we do it that way?'. It is easy to say that 'This is the way we do a certain technique because that is the way it was taught to me', or because one finds that 'this way works best'. Yet, this approach to the question does not help the student to understand the underpinnings of the technique. By answering this question in a meaningful way, discussing the physics, biomechanics, anatomy and physiology a coach will not only enhance the students' learning and understanding, but also make their coaching more professional.

This paper is centred around that simple question and how to answer it in a meaningful way with a focus on nage-waza. Although only a couple of techniques will be covered, the principles discussed are easily transferable to other throws, and at times other types of techniques such as strikes or holds. One such concept is Newton's Laws of Motion.

Newton's Laws of Motion

In this section the laws of motion set out by Isaac Newton will be discussed briefly and at the end, a technique will be broken down into steps to highlight when each law comes into play.

First Law- Inertia

Every body perseveres in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed thereon.

Probably the simplest of the laws, it states that an object will not move or alternatively will continue moving until something changes that. For nage-waza this translates simply, implying that until tori (the person who executes the technique) imparts some kind of force to uke (the recipient of the technique) (if uke does nothing) nothing will happen.

Second Law- Acceleration

The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the straight line in which that force is impressed.

In simplified terms, this law states that when a force is applied to an object, the object will move proportionately to that force (but must still overcome the inertia of the object if an effect is to be seen) and in the same direction of the force. In nage-waza, this means that if tori pushes, pulls or lifts uke he will accelerate in that direction in accordance with the force that is used.

Third Law- Action Reaction

To every action there is always opposed an equal reaction: or, the mutual action of two bodies upon each other are always equal, and directed to contrary parts.

This law states that for every action taken, there is an equal and opposite reaction. In jujitsu terms, this means that when tori imparts a force on uke, an equal and opposite force is applied to tori.

Application of Newton's Laws of Motion

Now that the laws have been outlined, O Goshi (major hip throw) will be broken down into its steps and the laws will be outlined more specifically.

1. Pre grip

The first law is at play now as uke will not move until a force is applied to him.

2. Taking grips and kuzushi (breaking balance)

In this step, both the second and third law can be seen. By breaking the balance, tori is applying a force to uke that will overcome his inertia and start to accelerate his mass (second law). The third law is also seen while breaking the balance, as when tori imparts a force to uke, an equal and opposite force is applied to tori but is mitigated by slightly leaning back or by tori bracing himself before starting to move (this is why tori and uke do not collide into each other).

3. Tsukuri (entry into technique)

In O Goshi, this part of the throw does not create a great deal of momentum; however in many other throws (see later, in Morote Gari) tai sabaki (body movement) is used to create momentum to help accelerate uke in the execution phase of the throw.

4. Kake (execution phase)

Again both the second and third laws are seen in this step. By lifting uke, it is pushing tori harder into the tatami, (third law), and by applying an upwards and rotational force to uke, tori is accelerating him up and over his body (second law).

5. Uke falls

As uke reaches the apex of the throw, gravity will take over and change his trajectory towards the ground (first law) and then he will start to accelerate towards the ground (second law).

6. Uke does breakfall.

As uke hits the tatami, the mat will push back up at him and stop his downwards movement (third law).

1. Kuzushi **2. Tsukuri** **3. Kake** **4. Uke falls** **5. Uke does breakfall**

Helpful biomechanical concepts

This section will introduce and outline the most important biomechanical terms, concepts and equations for nage-waza. This paper will not go into great mathematical detail as having a basic understanding of the equations will have the most impact on day to day coaching practices.

Velocity = displacement / time

Velocity is an important component of momentum and acceleration. As this equation would suggest, depending on changes to the distance travelled in a specific direction (displacement) and the time it takes to travel that distance, the velocity will change (Quick, 2016). To increase velocity, either the distance travelled needs to be longer in the same amount of time, the time it took to travel a certain distance needs to be quicker - or a combination of the two.

Acceleration = velocity / time

Acceleration is used to quantify the change in velocity and is important in determining force (Quick, 2016). To increase acceleration, either velocity needs to increase (by increasing displacement) or by decreasing the time in which the acceleration occurs.

Momentum = mass x velocity

Momentum is mass moving at speed (Quick, 2016); so for nage-waza, this can be a crucial component of a technique's success or failure. By increasing momentum, it is more likely that tori will be able to overcome the inertia of a static uke. To increase momentum either the mass needs to increase (hard to do in most cases, but can be achieved in some throws from switching from using one limb to the whole body, such as in O Soto Gari) and/or the velocity needs to increase (by increasing displacement and/or by decreasing time).

Force = mass x acceleration

Force is an important concept in breaking the balance withlifting throws (Quick, 2016). By increasing the mass in a throw (by using one's whole body or by combining tori and uke's weight by landing on uke while throwing) and/or acceleration (by having faster tai sabaki) force will increase.

Application of Biomechanical Concepts

Now that some terms have been clarified, Morote Gari (two handed reap) will be broken down to illustrate these terms and other helpful terms and concepts relating to balance that can be utilised in many different throws.

1. Tai sabaki (body movement)

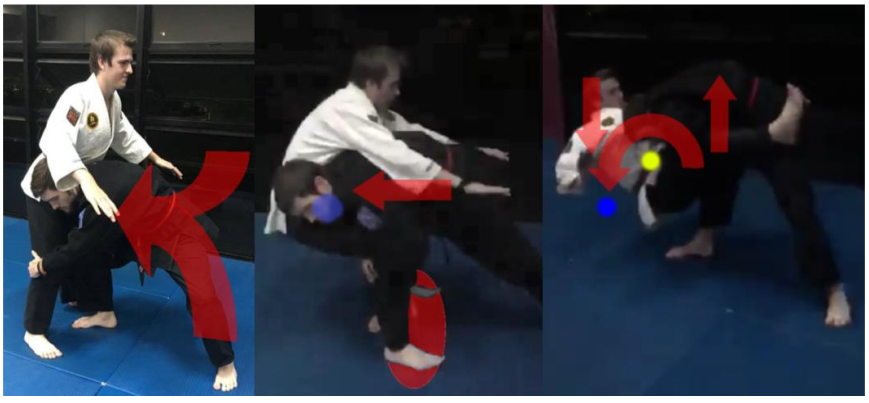
In this throw, tai sabaki is more than just tori putting himself into the right position. If done correctly, tori should have developed a significant amount of momentum (by tori dropping his weight and driving forward with some of the biggest muscle in the body - his legs) (Saladin, 2015, p. 355) while at the same time positioning his shoulder and hands in the correct position.

2. Kuzushi (breaking uke's balance with the shoulder)

Using the momentum generated via the tai sabaki, tori's shoulder breaks uke's balance moving his centre of gravity (represented by a blue dot on the below photos) outside of his base of support (represented by the red oval) accelerating him backwards. At this point, uke's legs will become lighter because his upper body is no longer over his feet and he is currently falling.

3. (Kake) (lifting uke's legs with the hands)

Now tori lifts the weight of uke's legs (again with another large muscle group, the back), tori's hands grab behind uke's knees. Anatomically this seems to be the best place to grab as the upper leg and calf muscles are usually too large to get a good grip and the ankles are too far away. However, behind the knees on the lateral side are tendons from the femoris muscle that allow for a firm grip (Saladin, 2015, p. 317). This will add force to the throw as uke's body will pivot around his **centre of mass** (represented by a yellow dot) accelerating his upper body into the mat.



1. Tai sabaki | 2. Tori breaks Uke's balance with his shoulder | 3. Tori lifts Uke's legs with his hands

Centre of gravity -v- centre of mass

Although these two terms are used interchangeably at times and are practically the same when one is standing in anatomically normal position, they do not mean the same thing (Wood, n.d, para. 2). Centre of gravity refers to the point inside or outside of an object that gravity appears to act on. In nage-waza it can be affected by the position of uke's limbs as well as in what position uke currently finds himself (such as standing or half way through a throw). Centre of mass refers to a point inside the body around which the mass is equal. During a throw, it can only be changed by the position of the limbs (centre of mass would be located higher on a person with their arms reached out overhead than a person in anatomically normal position).

Lever systems

Although it is uncommon and sometimes difficult to apply lever systems to nage-waza, this paper will briefly touch on the topic for the sake of full disclosure. It is a difficult concept to apply to throws as within a single throw, multiple types, or classes of lever systems can occur throughout the throw and indeed sometimes at the same time.

A lever system is made up of three components - the load or resistance, a fulcrum or axis and the force or effort all connected by a lever arm (Davidovits, 2010, p. 10). Depending on the positioning of these three components in relation to each other, this will determine the class of lever. The three lever classes include balance (first class), power (second class) and mobility (third class) (Quick, 2016). Tai Otoshi (body drop throw) will be examined for the lever systems and all three classes will be outlined in class order (not in the order occurring in the throw).

First class – Balance:

A lever that is represented with the fulcrum in the middle and a load and effort at opposite ends of the lever arm (Davidovits, 2010, p. 10). The portion of the lever arm is between the load and the fulcrum is referred to as the resistance arm and the portion between the fulcrum and the effort is the force arm (Quick, 2016). If the fulcrum is close to the load and a long force arm is present, this will achieve a mechanical advantage, meaning that it will be easier to lift the load. In Tai Otoshi, the first class lever is represented as the rotational movement that is part of the tai sabaki. With the load represented by uke, the fulcrum is the elbow of tori and the effort is coming from the muscle of tori’s back.

Second class – Power

This lever is represented with the load being in between the effort and the fulcrum (Davidovits, 2010, p. 10). This is useful for when lifting a heavy load. This is the same principle that a wheelbarrow works under. When the load is far away from the effort and close to the fulcrum, a mechanical advantage is achieved. In Tai Otoshi, this lever system is represented in the execution phase of the throw as uke is thrown over tori's leg. The load is again represented at uke with the effort coming from the muscles rotating the spine and the fulcrum is tori's leg.

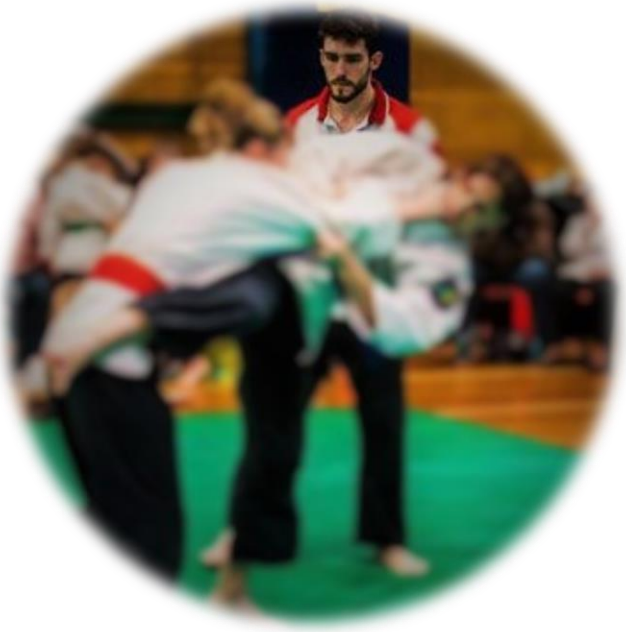
Third class – Mobility

This lever's effort is applied to the middle of the lever arm and the load and fulcrum are at either end (Davidovits, 2010, p. 10). This is easily pictured at a pair of tweezers. This lever system can be found in the breaking of the balance, as tori brings his fist to his ear in a 'hammer curl' like motion. This may seem at first glance like a first class lever system, but the prime mover in this movement is not the bicep as many would presume; it is a muscle called the brachioradialis which has its belly located in the lateral forearm (the origin is in the distal humerus, with its insertion at the distal end of the radius) (Saladin, 2015, p. 346). With this in mind, the load is uke, the effort is from the brachioradialis muscle and the fulcrum is the elbow of tori.

1 and 2. Third class lever system **3. First class lever system** **4. Second class lever system**

Conclusion

Jujitsu does not need to be an unthinking art bound by rigid ways of doing techniques. By analysing more scientifically about how techniques are taught, potentially this could lead to increased student understanding of techniques and allow people to move beyond the easy way out of 'this was how I was shown to do it' and become a better martial artist and coach.



"Act as if what you do makes a difference. It does." – William James

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