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Research article

A THREE-DIMENSIONAL ANALYSIS OF THE CENTER OF MASS FOR THREE DIFFERENT JUDO THROWING TECHNIQUES

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ABSTRACT
Four black belt throwers (*tori*) and one black belt faller (*uke*) were filmed and analyzed in three-dimensions using two video cameras (JVC 60 Hz) and motion analysis software. Average linear momentum in the anteroposterior (x), vertical (y), and mediolateral (z) directions and average resultant impulse of *uke's* center of mass (COM) were investigated for three different throwing techniques; *harai-goshi* (hip throw), *seoi-nage* (hand throw), and *osoto-gari* (leg throw). Each throw was broken down into three main phases; *kuzushi* (balance breaking), *tsukuri* (fit-in), and *kake* (throw). For the *harai-goshi* and *osoto-gari* throws, impulse measurements were the largest within *kuzushi* and *tsukuri* phases (where collision between *tori* and *uke* predominantly occurs). Both throws indicated an importance for *tori* to create large momentum prior to contact with *uke*. The *seoi-nage* throw demonstrated the lowest impulse and maintained forward momentum on the body of *uke* throughout the entire throw. The *harai-goshi* and *osoto-gari* are considered power throws well-suited for large and strong judo players. The *seoi-nage* throw is considered more technical and is considered well-suited for shorter players with good agility. A form of resistance by *uke* was found during the *kuzushi* phase for all throws. The resistance which can be initiated by *tori's* push or pull allows for the *tsukuri* phase to occur properly by freezing *uke* for a good fit-in. Strategies for initiating an effective resistance include initiating movement of *uke* so that their COM is shifted to their left (for right handed throw) by incorporating an instantaneous "snap pull" with the pulling hand during *kuzushi* to create an opposite movement from *uke*.

KEY WORDS: Biomechanics, impulse, kinematics, martial art, momentum, collision.

INTRODUCTION

Modern judo is an Olympic sport with roots dating back to the ancient martial arts of the samurai warriors. It incorporates a variety of throwing, pinning, choking, and arm lock techniques to subdue an opponent. Judo means the "gentle way" which reflects the philosophy of defeating an opponent with the least amount of effort or strength. Therefore, judo as a sport inherently emphasizes the use of proper technique and mechanics. To date, only a handful of studies have investigated judo from a biomechanical perspective (Harter and Bates, 1985; Imamura and Johnson, 2003; Minamitani et al., 1988; Pucsok et al., 2001; Serra, 1997; Sacripanti, 1989; Sannohe, 1986; Tezuka et al., 1983).

The founder of modern judo, Jigoro Kano

Table 1. Participant information.

Participant	Weight (kg)	Height (m)	Age	Rank (Degree Black)
1	84	1.78	22	*Shodan* (1^{st})
2	118	1.68	42	*Yondan* (4^{th})
3	89	1.78	32	*Sandan* (3^{rd})
4	75	1.68	39	*Sandan* (3^{rd})
Uke	89	1.75	38	Yondan (4^{th})

(1860-1838), formulated judo as a collection of ju-jitsu techniques that he felt were scientifically effective. Kano classified techniques into phases with the intent of developing judo through analytical thinking. Judo throwing techniques are comprised of three main phases: *kuzushi* the preparatory phase defined as breaking an opponent's balance or simply to prepare them for a throw, *tsukuri* the process of fitting into the throw, and *kake* the acceleration phase describing the execution of the throw itself (Kano, 1986). Although the judo literature has addressed phases and defined them in theory, it has yet to analyze them using biomechanical terms.

Analyzing the movement of an individual's center of mass (COM) is a general descriptor of whole body mass movement and has been used to study sport technique. Hay and Nohara (1990) used COM measurements to evaluate elite long jumpers in preparation for take-off. Other studies have investigated vertical oscillation of COM to differentiate running techniques (Williams, 1985). In addition, kinetic measures at the COM such as changes in momentum and impulse can be particularly useful for analyzing sports like judo since manipulation of an opponent's body motion through an applied force is the basis for all judo techniques. Impulse (I) is defined as the change in momentum (mv) and related to force (F) through the following equations: $I = F\Delta t$

where $F\Delta t = mv_2 - mv_1$ or $F\Delta t = \Delta mv$

Judo enthusiasts have long been intrigued by the concept of a perfect throw (Kano, 1986). Those who have experienced it in training or competition often describe it as effortless and requiring very little energy. This experience is generalized under judo's philosophy of maximum efficiency with minimal effort. To begin studying this phenomenon, analyzing the COM movement of *uke* during a simulated perfect throw may be an ideal approach, much like studying the mechanics of a ball player by analyzing the movement of the ball.

Currently there are very little quantifiable data on the biomechanics of judo. Therefore, the purpose of this study was to analyze COM information from judo players engaged in different types of throwing. This will provide a biomechanical basis of what the thrower (*tori)* and person being thrown (*uke)* are doing during the phases of various throwing techniques and ultimately provide a better understanding of the factors that constitute a mechanically efficient throw.

METHODS

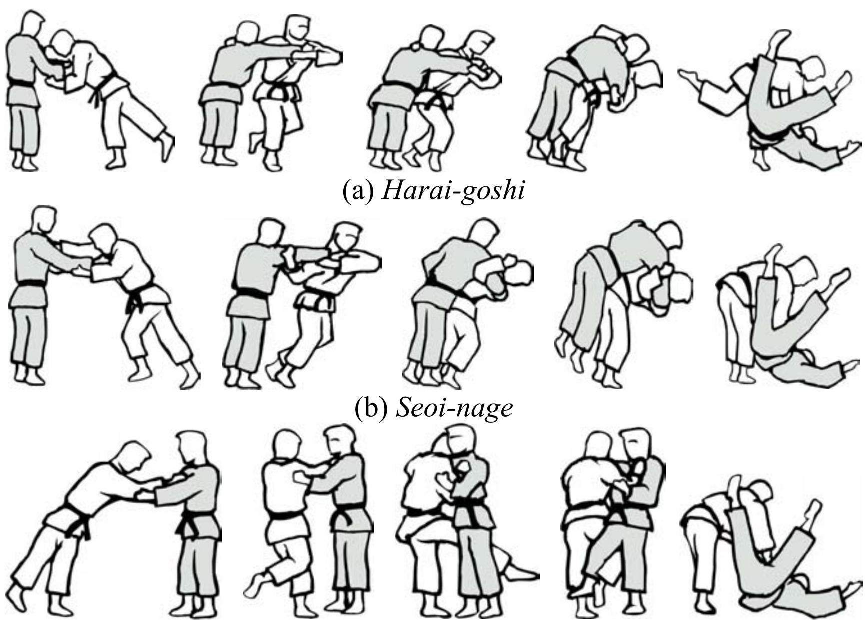
Four highly advanced (black belt) participants served as the *tori* for this study. A single highly advanced participant (black belt) was used as the *uke* and accepted the throws for all participants. All participants used in this study had at least 5 years of national competition experience. Information including age, weight, and height were collected for all participants (Table 1). All participants signed informed consent, consistent with University guidelines concerning the testing of human participants. Each participant performed three different types of throwing techniques: *seoi-nage* (hand throw), *harai-goshi* (hip throw), and *osoto-gari* (leg throw). To ensure an adequate combination of maximal effort and proper technique, the participants were required to perform the throws with maximal effort while maintaining their balance (staying on at least one foot and no more than one hand touching the ground) after the throw was executed. This procedure was designed to simulate throwing under ideal conditions, where *uke* began each throw in a stationary position and elicited no conscious resistance to *tori's* efforts. The procedure is similar to typical throwing practice, referred to as *nage-komi*.

Two video cameras (JVC 60 Hz) synchronized by LED were used to collect the data. The cameras were positioned approximately 90 degrees apart facing one side of *uke* and *tori* so that a sagittal view of the action was seen. Directions for the *harai-goshi* and *seoi-nage* throws were set such that *uke* always began each trial facing the positive x (anteroposterior) direction and his right shoulder facing the positive z (mediolateral) direction. For the *osoto-gari* throw the z orientation was changed such that *uke's* right shoulder was facing the positive z direction and the front of the body facing the negative x direction at the start of the throw. This process was to insure that *uke* was always thrown predominantly towards the positive x direction with his right shoulder initially facing the positive z direction. The upward direction was designated as positive y (vertical) for all throws. Power spectrum analysis consistent with the Nyquist Theorem indicated that 60 Hz was an adequate collection frequency for judo movements.

A three dimensional motion analysis system (Peak Performance Technologies, Inc., Englewood, CO) and the DLT (Direct Linear Transformation) procedure were used to analyze three-dimensional kinematic data. As judo requires that all participants wear a judo uniform (judo *gi*), joint markers could not be used. Therefore, manual digitization of 18 body points for both *tori* and *uke* were performed for all trials by a single digitizer who was experienced with the sport of judo. The digitized data were smoothed using a 4^{th} order zero lag Butterworth filter with a cut-off frequency of 5 Hz based on power spectrum analysis.

COM calculations were based on anatomical parameters from Clauser et al. (1969) and computed by the motion analysis software into a virtual point. COM momentum values were calculated using three-dimensional COM linear velocity measurements and participant mass. These values were averaged for each phase. Impulse values were calculated as the difference between average momenta of *tsukuri* and *kake* phases or the phases in which collision between the two bodies occur. Both descriptive and inferential statistics were used to interpret the data. Differences in momenta between phases, directions, and throws were statistically analyzed with a three-way repeated measures analysis of variance ($p < 0.05$). Differences in impulse between different throws were analyzed with a one-way repeated analysis of variance ($p < 0.05$). Tukey post hoc tests were used to analyze significant interactions. Only measurements based on the average COM momentum values of *uke* were reported in this study, since *uke's* motion is considered the product of *tori's* throw.

Since throwing phases have yet to be defined in biomechanical terms, they were set according to popular opinion in instructional literature (Kano, 1986; Kim and Shin, 1983; Koizumi, 1960; Harrison, 1952). The *harai-goshi* and *seoi-nage* phases were broken down in similar fashion. The *kuzushi* phase begins with the first movement towards the entrance of the throw by *tori* and ends with the placement of *tori's* supporting (left) foot to the ground so that both feet are planted on the ground. *Tsukuri* immediately follows *kuzushi* and begins with *tori's* feet pushing off the ground and ends with *uke's* heels beginning to rise from the ground. *Kake* immediately follows *tsukuri* and begins with *uke's* toes and feet rising from the ground, the body being thrown into the air, and ending when *uke's* body and any part of both legs hitting the ground (Figure 1). For the *osoto-gari* throw, *kuzushi* begins with the onset of *tori's* leg drive from the sweeping (right) leg allowing the supporting (left) leg to move towards *uke* and ends with *tori's* sweeping leg moving up to *uke's* body. *Tsukuri* immediately follows *kuzushi* and begins with *tori's* sweeping leg passing *uke's* body and ends with *tori's* sweeping leg making sweep contact. *Kake* immediately follows and begins with sweep contact to *uke's* body and any part of both legs striking the ground (Figure 1).



(a) *Harai-goshi*

(b) *Seoi-nage*

(c) *Osoto-gari*

Figure 1. Illustration of (a) *harai-goshi*, (b) *seoi-nage*, and (c) *osoto-gari* throws.

Table 2. Participant resultant impulse mean (N•s) and standard deviation values with force (N) and time (s) components for the *harai-goshi*, *seoi-nage*, and *osoto-gari* throws.

	Harai-goshi	***Seoi-nage***	***Osoto-gari***
Participant 1	(129.2)x(.68) = 87.8	(88.5)x(.86) = 76.1	(175.8)x(.70) = 123.0
Participant 2	(175.9)x(.61) = 107.3	(175.6)x(.67) = 117.7	(181.5)x(.72) = 130.6
Participant 3	(193.6)x(.55) = 106.5	(130.0)x(.67) = 86.1	(122.7)x(.73) = 89.5
Participant 4	(136.6)x.68) = 92.8	(87.5)x(.76) = 66.5	(145.4)x(.75) = 109.0
Mean	(158.9)x(.63) = 100.1	(120.4)x(.74) = 89.0	(156.3)x(.73) = 113.0
SD	9.9	18.8	17.7

RESULTS

Statistical analysis revealed significant differences in average COM momentum for each phase and each direction ($p < 0.001$). Thus, each throw demonstrated different momenta in the x, y, and directions during kuzushi, tsukuri, and kake phases. The seoi-nage depicted significantly different momenta from the harai-goshi and osoto-gari throws ($p = 0.008$), while the latter two were not significantly different from one another ($p = 0.069$). Resultant impulse values were not significantly different between throws ($p = 0.096$). Nonetheless, impulse as well as force and time components for each throw are reported to describe collision characteristics between tori and uke (Table 2). Comparing the three different types of throws, harai-goshi created the greatest force onto uke with a force value of 158.9N averaged over a period of 0.63s (time period of tsukuri and kake), followed by osoto-gari (156.3N; 0.73s), and seoi-nage (120.4N; 0.74s), respectively. The seoi-nage demonstrated the smallest impulse and force values indicating a relative weak collision between tori and uke.

DISCUSSION

In this study, it was assumed that *uke's* movement was the product of *tori's* effort to throw *uke*. Since all throws were considered "perfect throws" (no conscious resistance by *uke*), analyzing *uke's*

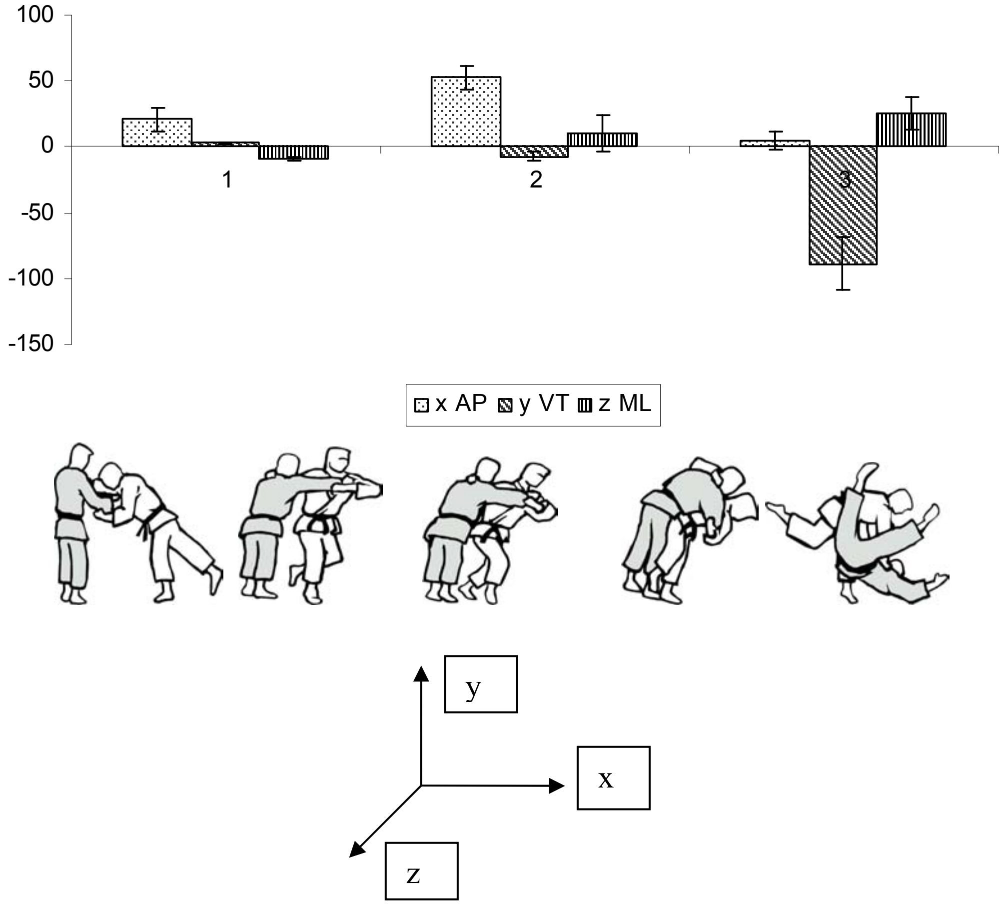


Figure 2. *Harai-goshi* throw momentum mean ((kg•m)/s) and standard deviation values in the anteroposterior (x AP), vertical (y VT), and mediolateral (z ML) directions (left to right columns respectively) for each phase (1 = *kuzushi*, 2 = *tsukuri*, 3 = *kake*).

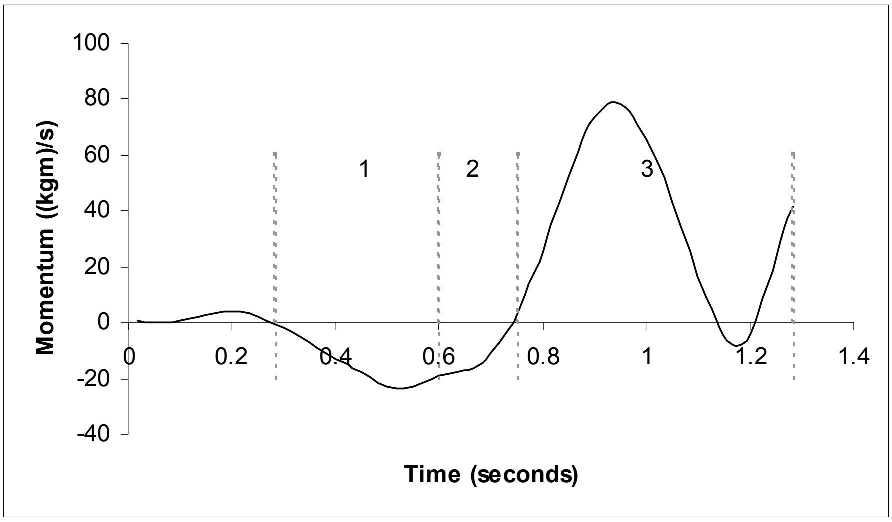


Figure 3. Illustration of momentum in the mediolateral (z) direction within the *kuzushi* (1), *tsukuri* (2), and *kake* (3) phases for the *harai-goshi* throw. A theoretical resistance by *uke* is present within phases 1 and 2.

movement would conceivably offer explanations as to what factors determine a perfect throw, a throw which competitors refer to as an *ippon* (full point) throw. Statistical analysis revealed that COM momenta in each direction for each phase of the throw were different. The following discusses COM momentum and impulse characteristics for each throw separately.

Harai-goshi (hip throw)

During the *kuzushi* phase *uke's* COM depicted momentum forward along the anteroposterior (x) direction, upward along the vertical direction (y), and moving away from *tori's* pulling hand (left hand for a right handed throw) along the mediolateral (z) direction. The *tsukuri* phase indicated a continuation of forward momentum, a change from an upward to a downward momentum, and a change in mediolateral momentum towards *tori's* pulling hand. The *kake* phase indicated a continuation of momentum forward, downward, and towards *tori's* pulling hand (Figure 2).

The *harai-goshi* throw in general terms is a hip toss with *uke* being thrown in the forward direction. The study indicated as such with *uke's* momentum increasing from *kuzushi* to *tsukuri* phases at 20.6 to 52.6 (kg•m)/s respectively. This can be considered a skilled trait by *tori* considering that they must continually pull *uke* forward while simultaneously shifting their feet and turning their body 180 degrees. The momentum is generated by the force created by *tori's* arms, most notably from the pulling arm (left arm), but ultimately originating from the pushing force of the feet or ground reaction force (Tezuka et al., 1983; Harter and Bates, 1985; Serra, 1997). Thus, the *harai-goshi* and judo throws in general incorporate a kinetic link between segments, where momentum is progressively increased from the feet, legs, trunk, to the arms (Morehouse and Cooper, 1950). Further analysis did indicate that peak momentum in the forward direction typically occurred just after right foot touch. Therefore, judo players should strive to create the greatest forward momentum on the body of *uke* just after right foot touch.

From *tsukuri* to *kake* phases, momentum in the forward direction sharply decreased from 52.6 to 4.6 (kg•m)/s respectively. This was representative of *uke* and *tori* colliding and likely explaining the sudden drop in *uke's* momentum. This observation is very consistent with the definition of *tsukuri,* in that, there is an attempt to fit into *uke* with close body contact through collision. From this perspective the *harai-goshi* throw requires the ability for the thrower to create large momentum either through high velocity, large mass, or both. Two of the heaviest players in this study created the greatest resultant impulse and force onto *uke*. Therefore, from a practical standpoint this throw may be better suited for heavy players with enough mobility skills to turn their body 180 degrees fairly quickly and create a plastic collision such that *uke* and *tori's* bodies become one.

Momentum of *uke* in the vertical direction for the *kuzushi* and *tsukuri* phases displayed a trend in the upward direction but was considered weak due to high standard deviation values. It is possible that the relative height of *tori* compared to *uke* affected these measurements. It is also possible that momentum generated in this particular direction, while important to the success of throw, is quite small. A study by Sannohe (1986) indicated that pulling upwards and forward with *tori's* pulling

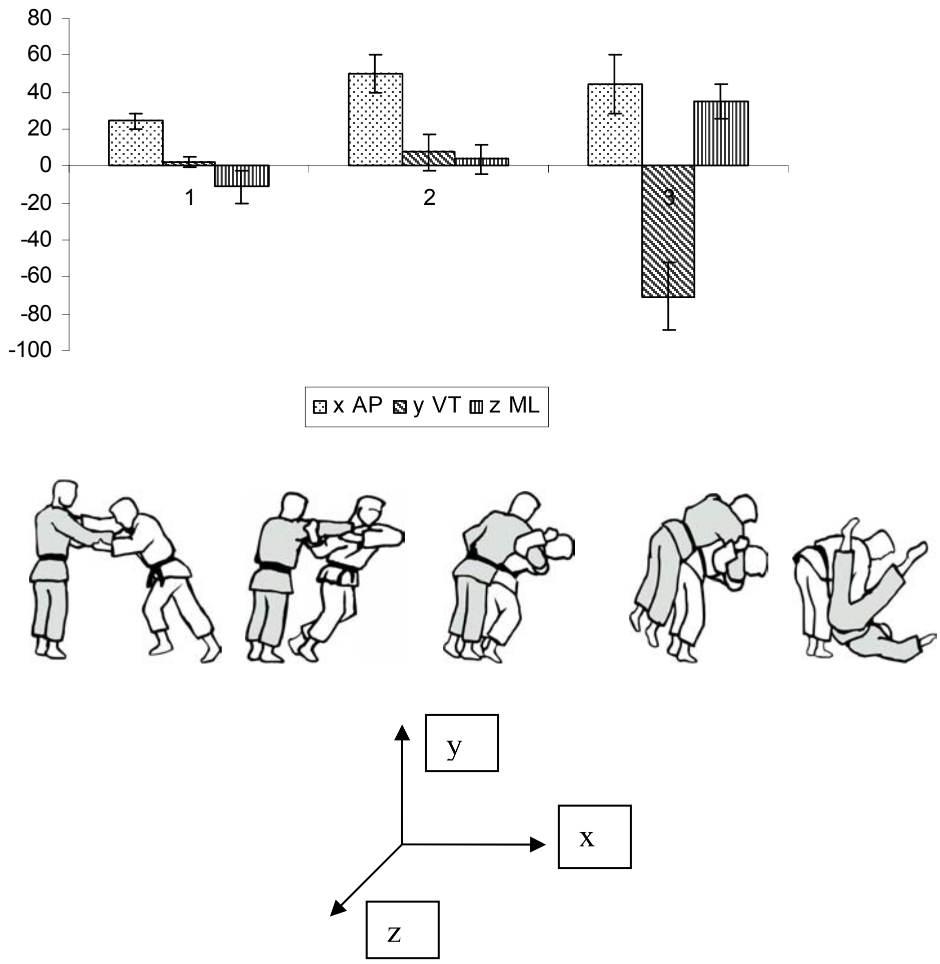


Figure 4. *Seoi-nage* throw momentum mean ((kg•m)/s) and standard deviation values in the anteroposterior (x AP), vertical (y VT), and side-to-side (z ML) directions (left to right columns respectively) for each phase (1 = *kuzushi*, 2 = *tsukuri*, 3 = *kake*).

hand at 10 degrees from above horizontal elicited the strongest angle of pull. The present study demonstrated a weak trend to substantiate this concept, since *uke's* body was moved upward by all participants during the *kuzushi* phase. However, it should be mentioned that the recommended angle of pull in the Sannohe (1986) study was determined through a pulley device and not under real throwing conditions.

Momentum in the mediolateral direction indicated a movement of *uke's* body away from *tori's* pulling hand during the *kuzushi* phase (-8.9 (kg•m)/s). Unlike the forward direction there was an opposite movement to the direction of the throw or what seemed to be a light resistance by *uke* in the mediolateral direction (Figure 3). By current definitions *kuzushi* is the phase in which *uke's* balance is broken in preparation for a throw, however, in this case *kuzushi* is not used to break balance but perhaps to elicit a slight resistance. This resistance in turn would allow *tori* to shift their feet, turn their body, and execute *tsukuri*. Thus, one can offer another definition of *kuzushi* in that it is a phase that allows the fit-in or *tsukuri* to occur.

***Seoi-nage* (Shoulder Throw)**

The *kuzushi* phase indicated momentum of *uke's* COM in the forward direction and away from *tori's* pulling hand in the mediolateral direction. There was a tendency for the COM to have upward momentum with only one participant creating a momentum downward. During the *tsukuri* phase there was a continuation of forward momentum. There was a tendency for upward momentum to occur with all but one participant creating a momentum downward. For the mediolateral direction two participants created momentum towards *tori's* pulling hand, while the other two created momentum away. During the *kake* phase there was a continuation of momentum in the forward direction, downward direction, and towards *tori's* pulling hand (Figure 4).

The *seoi-nage* throw is also considered a forward throwing technique with *uke* being tossed over the shoulder. Likewise, the results also indicated increasing forward momentum from *kuzushi* (24.5 (kg•m)/s) to *tsukuri* (50.2 (kg•m)/s) phases. There was also an indication of leg and trunk contribution through kinetic chain since the peak momentum during this phase was created just after right foot contact. Unlike the *harai-goshi*, however, the *seio-nage* throw maintained *uke's* forward momentum through the *kake* phase (44.6 (kg•m)/s) as well. This can also be considered a skilled trait by *tori* considering that they must also shift their feet and turn 180 degrees during the *kuzushi* phase of this throw. Since there was not a great change in *uke's* momentum from *tsukuri* to *kake* phases, collision may not be considered an important aspect of this throw. Likewise, the *seoi-nage* depicted the lowest resultant impulse and force values. Though impulse was not significantly different between throws, momenta generated by this throw were significantly different from the other two. The time period over which impulse occurred was surprisingly large considering that this throw is preferred by lighter and faster players. It is conceivable that collision force is actually larger than what was measured in this study, since the *kake* phase for *seoi-nage* tends to be longer than other throws due to *uke* being thrown over the shoulder and staying in the air longer.

Uke's movement pattern in the vertical direction was also considered statistically weak as depicted through the large standard deviation values. Only one participant was shown to create a downward movement onto *uke*. This participant was also the lightest and one of the shortest participants. It is possible that pulling *uke* upward is not intended to be used for breaking *uke's* balance for this throw, rather, it is used to open *uke's* armpit so *tori* can position their arm underneath. The short participant was likely able to do this without pulling *uke's* body upward to a large degree. In addition, it would explain how a person of short stature may be able to reach a desired angle of pull to generate and maintain forward momentum which seems to be the main premise of *seoi-nage*. This also may lend credence to the common opinion that *seoi-nage* is well suited for players of shorter stature.

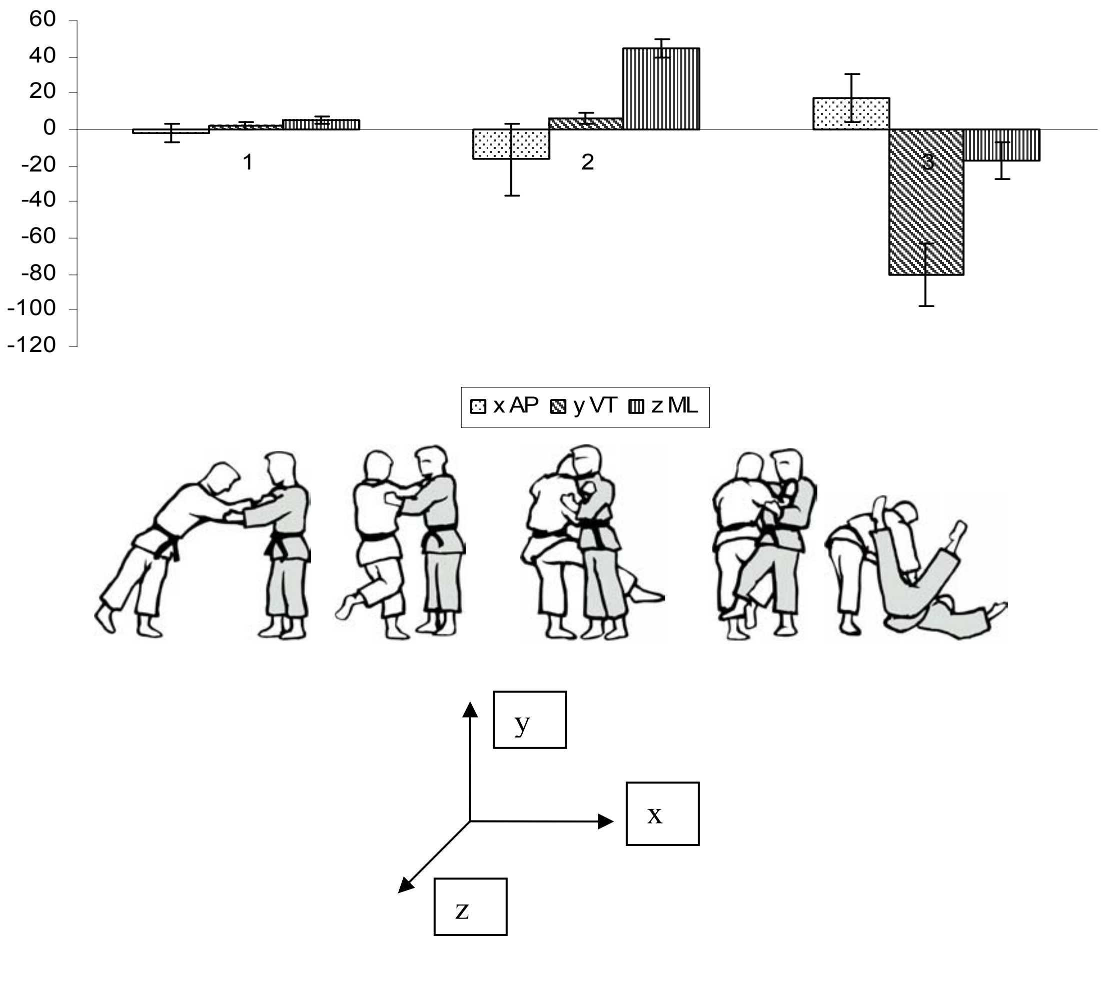


Figure 5. *Osoto-gari* throw momentum mean ((kg•m)/s) and standard deviation values in the anteroposterior (x AP), vertical (y VT), and side-to-side (z ML) directions (left to right columns respectively) for each phase (1 = *kuzushi*, 2 = *tsukuri*, 3 = *kake*). (Note: *uke's* forward movement is negative in this case and the z orientation is altered so that *uke's* right shoulder is facing positive z).

Uke demonstrated a resistance in the mediolateral direction during *kuzushi* (-11.3 (kg•m)/s). Thus, *kuzushi* is once again used to allow *tsukuri* to occur. Many instructors have taught throws conducive to this theory knowingly or not. They will tell students to "snap pull" during *kuzushi* which is considered a non-maximal quick and discrete pull. The shifting of *tori's* feet during *kuzushi* does not allow a maximal pull since the feet are often in the air. It is likely that the "snap pull" is used to create an instantaneous resistance by *uke* or freeze *uke* while *tori* regains foot position and obtains a tighter fit during the *tsukuri* phase. From a practical standpoint a judo player can use this resistance to their advantage by timing the execution of *kuzushi* when *uke* shifts their COM towards their left leg (for a right-handed throw). Some instructors will tell judo players to execute *seoi-nage* when *uke's* right foot begins to move forward. Considering this theoretical concept of resistance it would make sense, leaving *uke* with little alternative but to defend the throw by pushing-off with their right foot and shifting their COM towards the left. This application is conceivable for both the *seoi-nage* and *harai-goshi* throws.

Osoto-gari (leg throw)

Uke's COM had a tendency to move with forward momentum during the *kuzushi* phase with only one participant demonstrating momentum backwards. All participants demonstrated a momentum upward and toward *tori's* pulling hand during *kuzushi*. The *tsukuri* phase indicated forward momentum and a continuation of momentum upward and towards the pulling hand. *Kake* depicted momentum backwards, downwards, and away from *tori's* pulling hand (Figure 5).

Unlike the two previous throws, the *osoto-gari* tosses the *uke* backwards. Thus, one would expect *uke* to move backwards in all phases. However, this was not the case as *uke's* momentum increased from *kuzushi* to *tsukuri* in the forward direction at -1.9 (kg•m)/s and -16.7 (kg•m)/s respectively (negative sign depicting the forward direction for *uke* in this case). It wasn't until *kake* that *uke* moved backwards (16.9 (kg•m)/s). From these results, it is likely that *tori* actually pulls *uke* towards them while stepping into the throw during both *kuzushi* and *tsukuri*. It is also possible that *uke* once again creates a slight resistance to *tori's* push so that *tori* can properly fit into the throw. This is in agreement with Imamura and Johnson (2003) who found chest to chest contact and *tori's* upper body angular velocity as an important aspect of *osoto-gari*. Thus, judo players should strive to create large chest to chest collision onto *uke* through a combination of pushing momentum created by the right foot push-off via kinetic chain and pulling momentum created by the arms.

Imamura and Johnson (2003) also indicated very little movement of *uke* in the vertical direction during *osoto-gari*. The current study indicated a pattern of upward momentum during the *kuzushi* and *tsukuri* phases although the values were small with a large standard deviation. Likewise, this was evident in all three throws analyzed in this study.

In the mediolateral direction there was no indication of a resistance from *uke*. Rather *uke's* body moved towards *tori's* pulling hand with the greatest momentum being created during the *tsukuri* phase. Thus, *tsukuri* tends to be a particularly important phase for this throw. Again, these findings agree with Imamura and Johnson (2003) and the front-to-back findings of the present study, which suggest that chest to chest contact is very important for *osoto-gari*.

The results also indicated an importance for large momenta being generated for this throw, particularly in the anteroposterior and mediolateral directions. The average resultant impulse for *osoto-gari* was similar to that of *harai-goshi* indicating the importance of a strong collision between *tori* and *uke*. Since *osoto-gari* does not require a 180 degree turn of *tori's* body, it is often considered an easier throw to execute. From this perspective it is well suited for players with limited mobility skills and heavy players who can generate large momentum before contact.

CONCLUSIONS

Three different but mainstream judo throwing techniques were used for this study. Likewise, biomechanical similarities and differences were found for each. Judo throws can be viewed as collisions between two bodies, therefore, impulse characteristics of *uke's* body were considered representative of collision magnitude or, in this case, throwing power. The *osoto-gari* and *harai-goshi* throws created the largest impulse onto *uke's* body, therefore both throws can be considered "power throws" and likely well-suited for large and powerful individuals. The *seoi-nage*, on the other hand, created the smallest impulse and force onto *uke*. This throw was unique in that it maintained a large forward momentum on *uke's* body even after body contact. This indicated that this particular throw does not require size and strength from *tori* for better collision but rather shorter stature, speed, and skill to fit-in underneath the body of *uke* and roll them over their shoulder without compromising forward momentum.

A form of resistance by *uke* was found in the mediolateral direction during the *kuzushi* phase for both forward throws. This was based on a slight increase in momentum of *uke* in the opposite direction of *tori's* pull. This allows the next phase, *tsukuri*, to occur. If *uke* does not offer any resistance during *kuzushi*, *tori* will not be able to achieve a complete fit-in and will lose upper body contact with *uke*. Creating this type of resistance can also be described as freezing *uke* temporarily. Intuitively one can envision fitting into a stationary opponent more easily than one that is moving. Although the *osoto-gari* did not demonstrate this concept in the mediolateral direction, it did indicate it in the horizontal direction. Consequently, it is possible that a form of this theoretical resistance is present in all throwing techniques. Highly skilled judo players have developed the ability to initiate this resistance whether they are conscious of it or not. Undoubtedly it takes years of training to develop the proper timing necessary to execute it well. While the results of this study do not presume to replace years of judo training, it does offer a pragmatic approach to learning a skill that has long been held mystic in nature.

It would be interesting to quantify the amount of resistance allowed for a successful throw. One can assume that the resistance must be very slight and instantaneous. If the resistance is too large or strong, *uke* has performed proper defense and the throw will not work. It is also important to clarify whether or not this resistive force is created by *uke* or merely the consequence of *tori's* force, for example, *uke's* limbs moving in the opposite direction of *tori's* push or pull in the form of an inertial lag. Clearly, more research is needed to study this concept further. Some suggestions include analysis of judo players executing *ippon* (full point) throws during competition, similar analysis comparing novice and skilled judo players, and studies using kinetic measures via force plates to analyze the motion of *uke*.

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KEY POINTS

- The degree of collision between the thrower (*tori*) and person being thrown (*uke*) may be a reflection of throwing power.
- The hip throw (*harai-goshi*) and leg throw (*osoto-gari*) created large collisions onto *uke* and are considered power throws well-suited for stronger and heavier players.
- The shoulder throw (*seio-nage*) created small collisions onto *uke* emphasizing the importance for skill rather than strength.
- A theoretical resistance to *tori's* pull was found during the *kuzushi* phase indicating a propensity for *uke* to freeze and allow *tori* to better fit into the throw during the *tsukuri* phase.

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