６．釣り手の位置が異なる３種類の体落を掛けた時の受の運動学的研究

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６．A Kinetic Study of *Uke* During *Tai-otoshi* Using Three Different Grips

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要　約

釣り手の位置が異なる３種類の体落を掛けた時の受の体勢を運動学的に分析した。先行研究において、投げられる直前に受の体勢に一定の反応がみられることが知られている。それは取の押し引きに対して受がわずかに抵抗した反応を示すというものである（今村ほか2007）。取の力に対して受が体を硬直させるような反応は、取に“崩し”と“作り”をやり易くさせていると思われる。本研究は体落の投げにおいて、受の一定の反応が起こるかどうかを検証することが目的であった。

５名の柔道経験者は、フォースプレート上の受を異なる３種類の体落で投げた。３種類の体落とは釣り手が前襟(Tタイプ)、奥襟(Cタイプ)、背中(Bタイプ)の場合であった。受の動きに伴うフォースプレート上の力（Fxは前後、Fyは左右、Fzは上下方向）が測定された。それぞれの投げにおける力の最大値の平均を代表値とし、崩し・作り局面におけるこれらの力の出現時点を百分率で算出した。

Tタイプは上方向の力が最も大きかった。これは取の釣り手が受の脇下から持ち上げるように働くからである。これに比べ、CとBタイプは上から押さえつけるように釣り手を用いるため、

下方向への力が大きくなった。引き手側(PS)への力は崩し・作り局面の終盤に加速された。特にBタイプにおいて、この方向への力が大きいのは釣り手も引き手側に大きな力を加えることができるからだと思われる。

崩し・作り局面の中盤の釣り手側(LS)への力は取の引き手側への力に対する受の抵抗力であり、また終盤にみられた受の後ろ方向(BKW)への力は取りの前方向への引きに対する受の抵抗力であると思われる。これらのデータは抵抗性反応理論を示唆するものであった。即ち、取は受を崩し、自らの体勢を作る時、受の一定した反応を利用して、いわゆる受の体勢を剛体にしていると考えられる。

Introduction

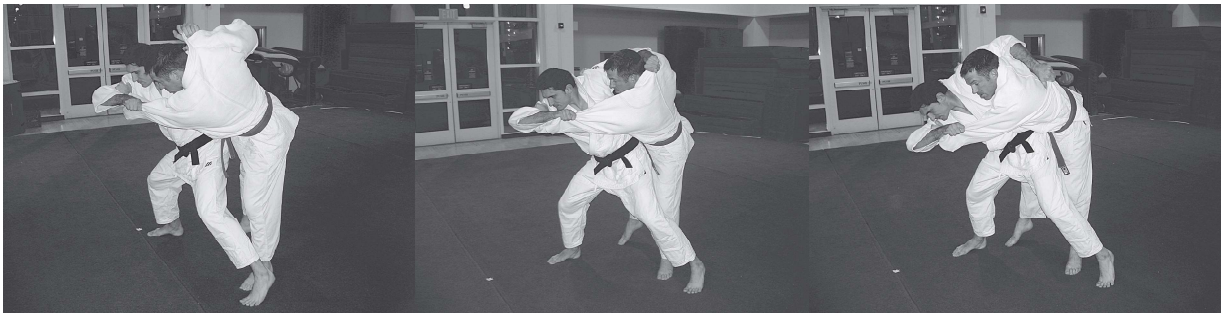
Despite judo's popularity around the world, research concerning the biomechanics of judo remains sparse. Likewise, the strategies used to analyze judo are still somewhat unrefined. A majority of the available research has concentrated on the actions of the thrower, or *tori*, using force plates, video capture, accelerometers, and electrogoniometers to analyze the biomechanics of various throws. While this approach is necessary and a logical first step, one must consider that judo is always performed with a partner. In this sense, it is also a logical to study judo by analyzing the person being thrown. As of yet, few studies have analyzed the biomechanics of *uke*.

Analyzing the actions of *uke* can be very telling as to the effectiveness of *tori's* throw. If one can envision analyzing a baseball as a product of a pitcher's throw or a basketball as a product of a person's free throw, then its is not difficult to consider analyzing *uke* as a product of *tori's* judo throw. Previous studies have attempted to analyze *uke's* center of mass (COM) to determine if certain body kinematics act as precursors to successful throws. Ishii et al. 2005 used video analysis to measure COM positions during successful *osoto-gari* throws during tournament play and found that *uke* who shifted their center of mass towards their toes and towards *tori* were more likely to be thrown than *uke* who kept their center of mass near their heels. Imamura et al. 2006 and Imamura et al. 2007, also used video analysis to measure COM momentum during simulated laboratory throws. They also found that *uke* shifted their COM towards *tori* during *osoto-gari* and described it as a small reactionary push to *tori's* push. Interestingly, similar resistance was found for *seio-nage* and *harai-goshi* throws, in that, when *tori* pulled *uke* there was a slight reactionary pulling away by *uke*. This phenomenon was found to occur during the *kuzushi* phase prior to successful throws and was hypothesized as a necessary occurrence for *tori* to successfully throw *uke*.

Force plate readings are indicative of net forces and accelerations created by the body and, in the case of judo, created onto the body. Since the COM is the point at which net forces and accelerations act, analyzing COM characteristics can also be accomplished through force plate analysis. Therefore, the purpose of this study was to analyze COM characteristics of *uke* during the throw *taiotoshi* using a force plate.

Methods

Five subjects with at least *ni-kyu* (2nd Brown) experience served as *uke* for this study. An Advance Mechanical Technology Inc. (AMTI) force plate capturing at 240 Hz was used to measure the net forces of subjects who were thrown by *tai-otoshi* (body drop throw) with three different types of grip. The normal lapel grip was considered the traditional method (T). The collar (C) and back grips (B) were considered alternative methods (Figure 1).



(T)　　(C)　　(B)

Figure 1. Illustration of *tai-otoshi* using three alternative grips, the traditional (T), collar (C), and back (B) grips.

図１．典型的な前襟（T），奥襟（C），背中（B）を握った３種類の体落

For each grip type, the subject was thrown three times with maximum effort. The force plate was large enough such that the subject stood completely on the force plate prior to being thrown. Maximum anteroposterior (Fx), mediolateral (Fy), and vertical (Fz) forces reported in terms of body weight (BW) were averaged for each trial and compared across throw type. The directions for Fx were further defined as forward force (FW) and backwards force (BKW), Fy as pulling side (PS) and lapel side (LS), and Fz as downward (DWN) and upward (UPW) forces (Figure 2).

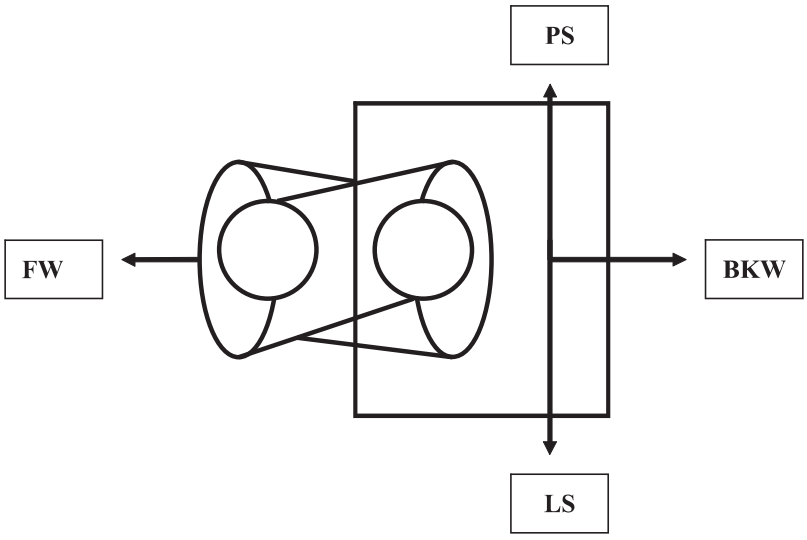


Figure 2. A diagram illustrating backward (BKW), forward (FW), pulling side (PS), and lapel side (LS) forces.

図２．後方（BKW），前方（FW），引き手側（PS），釣り手側（LS）の力

Throw time (TT) was recorded by locating significant increases in Fx and Fy forces and setting this as the starting point and locating air phase and setting this as the ending point. Because TT began when forces began to significantly increase and ended when *uke* left the force plate, TT described the amount of time it took to complete the *kuzushi* (balance breaking) and *tsukuri* (fit in) phases of the throw. TT was also compared between throw types.

Results

Upon completion of data collection, it was found that FW force was present in only 2 of 5 subjects, so averages were not recorded nor reported. On the other hand, PS forces were present in 4 of 5 subjects, so averages were recorded and reported. All other variables were present for all trials. Maximum values and throw time were averaged and are presented in Table 1.

	BKW	PS	LS	DWN	UPW	TT
Traditional (T)	0.35	0.11	0.14	1.18	0.57	0.54 s
Collar (C)	0.36	0.14	0.13	1.24	0.67	0.54 s
Back (B)	0.28	0.17	0.14	1.20	0.74	0.52 s

Table 1. Average maximum values in body weight (BW) for backwards (BKW), pulling side (PS), lapel side (LS), downward (DWN), upward (UPW) forces, as well as, average throw time (TT) for tai-otoshi with three different grips.

表１．３種類の体落における後方，引き手側，釣り手側，下方，上方の体重あたりの力の最大値の平均と投込時間の平均

The occurrences of these maximal forces were also determined as a percentage of total throw time, which was defined as the *kuzushi* and *tsukuri* (KT) of the throw. For example, it was determined that, on average, LS maximum force occurred at 52% of KT during the traditional *tai-otoshi* throw. The percentage occurrence for all forces and throws are presented in Table 2. A sample graph of one trial illustrates the forces occurring over KT (Figure 3).

	BKW (%)	PS (%)	LS (%)	DWN (%)	UPW (%)
Traditional (T)	86	76	52	11	45
Collar (C)	85	79	43	43	54
Back (B)	85	77	44	32	48

Table 2. The average occurrences of maximum forces backwards (BKW), pull side (PS), lapel side (LS), downward (DWN), and upward (UPW) as a percentage of throw time for three different type of taiotoshi.

表２．３種類の体落における崩し・作り局面の後方，引き手側，釣り手側，下方、上方の力の最大値が出現する時点の平均

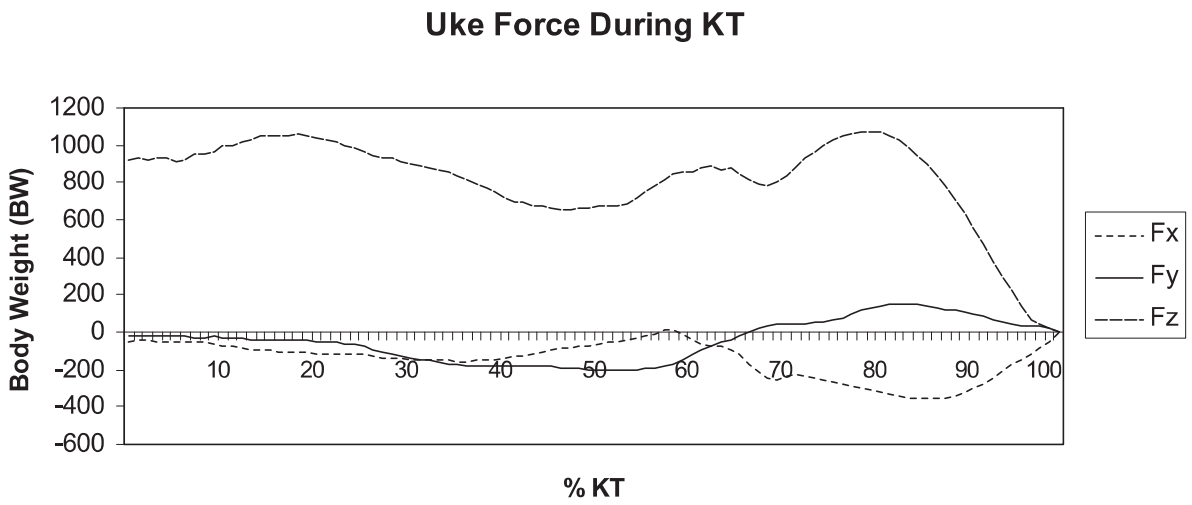


Figure 3. A sample graph of *uke's* force and time of occurrence as a percentage of KT.

図３．崩し・作り局面において受の力が変化する一つの事例を示した

Discussion

The forces created by *uke* were assumed to be the net forces of *uke* and *tori* interacting together. Therefore, forces measured in this study may be the result of *tori's* push or pull onto *uke*, *uke's* resistance to *tori's* push or pull, or a combination of both. According to the percent occurrence time, three forces were found to occur maximally during the early to middle portion of KT. LS force occurred at 52%, 43%, and 44% for T, C, and B throws, respectively, while UPW force occurred at 45%, 54%, and 48% for T, C, and B throws, respectively. This meant that maximum LS and UPW forces were occurring at about the same time on a fairly consistent basis. On the contrary, maximum DWN force was found to occur during the earliest part of KT at 11%, 43%, and 32% for T, C, and B, respectively. Since there was too much disparity between these times, it was deduced that maximum DWN force did not occur at the same time. In addition, when looking at separate trials, it was found that maximum DWN force occasionally occurred even before KT started. The remaining two forces, BKW and PS, occurred consistently later during KT. BKW and PS occurred at 86%, 85%, 85%, and 76%, 77%, 79% for C, T, and B throws, respectively.

In relation to the actual throw itself, LS force was determined to be *uke's* reactionary force from *tori's* pulling hand. In other words, as *tori* began the throw by pulling *uke's* sleeve sideways, *uke* created a resistance force in the other direction. These findings were very similar to those of Imamura et al. (2006) and Imamura et al. (2007), who found COM momentum movements in this direction during the KT phase. Although the momentum values were small, they were consistently present near the same time. Likewise, the present study also indicated that the resistance values were small averaging 0.14 BW or 14% of BW force. Collectively, the studies indicate that this resistance is likely not a conscious defensive maneuver but rather an unconscious form of resistance either through *uke's* inertia or *uke's* indecisive reaction of freezing. Imamura et al. 2006 alluded to these possibilities, in that, during an ideal

throw *uke* does not resist with large amounts of force but resist with a small amount. In this respect, a slight resistance by *uke* is actually beneficial so that *tori* may execute a good *tsukuri*.

Comparing LS force across throw type, it was evident that a similar slight resistance is present in all three types of *tai-otoshi* and may very well be present in all successful forward throwing techniques.

Another force component that occurred near the early to middle part of KT on a consistent basis was UPW. By definition, UPW force was net forces of *uke* acting in the upward direction. These measurements were taken as minimal values that fell below BW. Likewise, it was deduced that UPW force was the result of *tori* pulling *uke* upwards during KT, making them momentarily lighter. This maneuver is common in many forward throwing techniques and *tai-otoshi* seems to be no exception. Interestingly,

UPW values were different between grip type. The T *tai-otoshi* elicited the least amount of UPW force, which indicated that this style tends to lift *uke* more than the other styles. This makes intuitive sense since the T style places the elbow of the lapel hand underneath the arm pit of *uke* in a position that would create greater lift. Not surprisingly, the C and B *tai-otoshi* created the least amounts of lift. The collar and back grip likely created more downward forces during KT making UPW forces larger. Although maximum DWN forces did not occur consistently during KT, it did substantiate the UPW findings. The C and B throws did elicit greater maximum DWN force compared to the T throw, which may explain why the UPW values were greater for the C and B throws and less for T throw.

BKW and PS forces occurred consistently towards the end of KT. The PS force occurred first, near 77% of KT, and likely represented the acceleration of *uke's* COM towards *tori's* pulling hand. Unlike the previous forces which occurred early, the PS force represented the effects of *tori's* pull as *uke's* body began to accelerate into the kake phase (throwing phase). Not surprisingly, the PS force was largest for the B *tai-otoshi* (0.17 BW or 17% BW), which allowed for extra pushing acceleration by the back grip towards the pulling hand. The BKW force was the last maximum force recorded, occurring near 85% of KT. This backwards force represented *uke's* last resistance to *tori's* forward pull. It's interesting to consider that, although *tori* was thrown forward, there was not enough data to justify net forward forces occurring for *uke* on a consistent basis. This meant that most of the net BKW force was coming from *uke's* resistance to *tori's* forward pull and that forward acceleration of *uke's* body did not occur until *uke* left the force plate, or when *uke* began the kake phase. This further justifies the notion that successful throws occur when *uke* is slightly resisting or rigid. In this sense, one can say that *uke* falls instantaneously, where *uke* registers a backwards resistance force then immediately gets thrown into air phase without registering a forward acceleration. Again, this type of pattern indicates that *uke's* body must have provided enough resistance to be rigid enough to be thrown instantaneously but did not provide enough resistance to repel the throw.

Conclusion

Few research studies on the biomechanics of judo have studied the faller, or *uke*. Previous research studies using video analysis have indentified certain tendencies in *uke's* actions prior to being thrown. A theory of reaction resistance was used to describe *uke's* tendency to slightly resist *tori's* push or pull prior to being thrown. It was thought that this tendency was a necessary occurrence which allowed *tori* to create a good *tsukuri* on a rigid body. The purpose of this study was to further investigate this theory using *tai-otoshi* with three different grips via force plate measurement.

Five experienced judo players served as *uke* and were thrown with *tai-otoshi* using three different grips. Maximum values for Fx (forward (FW) and backwards (BKW)), Fy (pulling side (PS) and lapel side (LS)), and Fz (upward (UPW) and downward (DWN)) forces were averaged over three trials for each throw. The occurrence of these force were also measured as a percent of total throw time, which was considered as the time it took to complete the *kuzushi/tsukuri* (KT) phase.

Differences in throw type were predictable. The traditional *tai-otoshi* (T) demonstrated the least amount of UPW, which indicated large lifting forces by *tori* onto *uke*. This was further substantiated by the large DWN force created by collar grip (C) and back grip (B) throws due to the over the top nature of the collar and back grips. PS force was considered the acceleration of *uke's* body at 77% of kuzushi and tsukuri (KT) just before the kake phase. PS force was the highest for the B throw due to the over the back grip, which allowed for a greater sideways push from *tori* towards their pulling hand. The data substantiated the theory of reaction resistance.

LS force was considered *uke's* slight resistance force (14% BW) to *tori's* sleeve hand pull (to the side) which consistently occurred near 48% of KT. BKW force was considered *uke's* resistance (32% BW) to *tori's* forward pull which consistently occurred near 85% of KT. Both forces indicate *uke's* propensity to become rigid so that *tori* may execute a good *tsukuri* and perform a successful throw.

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