

6. 背負投の崩し・作り局面における引き力と床反力のタイミング

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6. Timing Characteristics of Pulling Force and Ground Force During *Kuzushi* and *Tsukuri* Phases of *Seio-nage*

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要 約

本研究の目的は背負投の「崩し・作り局面」における取の引き手速度と床反力の関係を明らかにすることであった。被験者は熟練者（有段者）1名と非熟練者（無段）1名で、それぞれ背負投を行った。受は熟練者（有段者）1名で両方の被験者の背負投を受けた。2台のビデオカメラ（60Hz）はLEDで同期され、三次元分析のためにDLT法による三次元動作解析システムが用いられた。取の引き手の手首の速度と受の重心速度が測定され、技能レベル間において崩し・作り局面におけるそれらの効果を比較した。背負投施技中のタイミングを比較するために、両被験者の時間は崩し・作り局面を100%となるように標準化された。結果は以下のとおりであった。

取の手首の速度と受の重心速度は熟練者において大きな値であった。床反力を推定するためにみた足の床への接地は手首の2か所の最大速度と関係していたが、これは引き手のパワーと床反力の関係を示すものであった。熟練者の手首の速度ピークは最初の足の踏み込みと同時であったが、非熟練者は手首の速度ピークは第1歩の足の床接地後であった。これらのデータから足の床への接地は引き力と関係し、引き力と床接地のタイミングは技能レベルやパフォーマンスの指標となる可能性が示唆される。

Introduction

Kodokan judo categorizes throwing techniques into phases, each according to the purpose or function of movement. The *kuzushi* phase is characterized by the thrower's (*tori's*) attempt to break the opponent's (*uke's*) balance prior to throwing. The *tsukuri* phase directly follows *kuzushi* and is characterized by *tori* fitting the throw into *uke*. The *ake* phase is the final phase characterized by the throw itself. Phase classification was developed for the purpose of analyzing judo from a scientific basis. Thus, using phases is a logical and appropriate method for studying the biomechanics of judo throwing techniques.

Studies have attempted to explain the basis of phase descriptions to a certain degree. Kinematic studies have investigated the center of mass (COM) movement of *uke* and *tori* during various phases. Imamura et al. (2006) measured COM velocity of *uke* during *kuzushi* and found a resistance to *tori's* efforts. This resistance pattern by *uke* was thought to be necessary for *tori* to create an effective "fit-in" during *tsukuri*. Imamura et al. (2007) performed a similar study with COM comparing *harai-goshi* under simulated and competitive situations. They found possible precursors to the *ippon* throw by looking at the movements of both *tori* and *uke*. The study also found difficulty in determining a clear difference between *kuzushi* and *tsukuri* phases, particularly during the competitive condition. Ishii et al. (2005) analyzed COM positions of *uke* precluding an *ippon* score (i.e. *kuzushi/tsukuri* phases) during competition for the throw *osotogari*. They also found possible precursors to *ippon* by looking at *uke's* position of COM relative to their base of support. The previous studies demonstrate similarities in their attempt to define the ideal circumstances prior to a successful throw and further define the importance of *kuzushi* and *tsukuri*.

Under basic physical law, movements must have an origin of force. For humans and judo players alike this force is generated from the contraction of muscle. The contraction of muscle, in turn, is composed into ground reaction forces (GRF) which allows the body to accelerate and move. With this in mind, a number of studies have measured the GRF of *tori* during judo throws (Tezuka et al. 1983; Harter and Bates, 1985; Pucsock et al. 2001) . In terms of phases, Harter and Bates (1985) described a GRF pattern for the *harai-goshi* throw consistent with the original phase descriptions by *Kodokan* judo. They found a pull-push-pull GRF pattern which seemed to mirror the intent of *kuzushi* (pulling *uke* off-balance) , *tsukuri* (pushing into *uke* or fitting-in), and *ake* (pulling *uke* once more to throw) . Although the phases were not directly addressed during this study, it shed light on the biomechanical purpose of *tori's* actions from a force generating perspective.

The purpose of this study was to continue investigations into the definition of throwing phases presented years ago by Jigoro Kano. The study also seeks to identify possible biomechanical markers that precede an ideal throw by combining concepts of body movement (kinematics) and body force generation from the ground (kinetics) . Specifically, the study serves as a preliminary investigation to the relationship between *tori's* pulling force and ground force during the *kuzushi/tsukuri* (KT) phase of the throw *seio-nage*.

Methods

One advanced (black belt) subject and one novice (white belt) subject served as the *tori* for this study. A single advanced subject (black belt) was used as the *uke* and accepted the throw for both subjects. Information including age, weight, and height were collected for all subjects (Table 1). Each *tori* subject performed the *seoi-nage* throw (hand throw) from the right-handed position. To ensure an adequate combination of maximal effort and proper technique, the subjects were required to perform the throw with maximal effort while maintaining their balance (staying on at least one foot and no more than one hand touching the ground) throughout the entire throw. This procedure was designed to simulate a “perfect throw” with no conscious resistance from *uke*.

Table 1. Subject Information

表 1. 被験者の特性

Subject	Weight (kg)	Height (m)	Age	Rank (Degree Black)
Advanced	89	1.78	32	3dan (3 rd)
Novice	90	1.80	20	White Belt
Uke	89	1.75	38	4dan (4 th)

Two video cameras (JVC 60 Hz) synchronized by LED were used to collect the data. The cameras were positioned approximately 45 degrees apart facing one side of *uke* and *tori* so that a sagittal view of the action was seen. Directions for the throw 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. This process insured 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.

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. Since 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 by a single digitizer for both trials. The digitized data were smoothed using a 4th order zero lag Butterworth filter with a cut-off frequency set by the Peak software optimization technique. COM calculations were based on anatomical parameters from Clauser et al. (1969).

Throwing phases were based upon *Kodokan* instructional literature (Kano, 1986). In light of the difficulties in determining the dividing point between *kuzushi* and *tsukuri* (Imamura et al. 2007), this study combined the two phases into one with the understanding that *kuzushi* always precedes *tsukuri*. Thus, the *kuzushi/tsukuri* (KT) phase for the *seoi-nage* throw began with the first movement towards the entrance of the throw by *tori*, followed by the placement of *tori*'s

feet to the ground, and ended when *uke's* heels began to rise from the ground. The KT phase is illustrated in Figure 1.



Figure 1. Three pictures describing the sequence of kuzushi/tsukuri (KT) for seio-nage: 1) tori's initial forward movement, 2) tori's two feet contact, 3) uke's heel lift.

図1. 3つの図は背負投の崩し・作り局面を表している。

1) 取の最初の前方向への動き, 2) 取の両脚支持, 3) 受の踵の浮上

Tori's pulling wrist velocity and *uke's* COM velocity were measured to analyze the effectiveness of *kuzushi* and *tsukuri* between skill levels. Time for both subjects was normalized such that the KT phase constituted 100% of total time. This was done to compare timing characteristics of wrist velocity and foot contact between subjects of different skill level.

Results

As expected, the advanced player created greater peak wrist velocity in all three directions of pull during the KT phase. The direction of pull pattern was the same for both subjects, the wrist velocities occurred forward (positive x), to *uke's* right (positive z), and upward (positive y). The peak velocity of *uke's* COM was greater for the advanced subject for the x and z directions but not for the y direction. The pull pattern of peak wrist velocity mirrored that of *uke's* COM peak velocity. The data indicated that *uke's* body moved forward, to their right, and upward.

The instant of foot contact with the ground served as an inference to GRF contribution. For the advanced subject the first foot contact occurred at 57% of the KT phase, while the second foot contact occurred at 85%. For the novice subject the first and second foot contact occurred at 33% and 85% of KT, respectively. The total KT phase time was similar at 1.15 seconds for the advanced subject and 1.16 seconds for the novice subject. Table 2 illustrates the peak wrist velocities for *tori* and peak COM values for *uke* as well as the percentage of occurrence within the KT phase.

In terms of timing, peak resultant (r) wrist velocity occurred near the first foot contact for both subjects (Table 2). The advanced player's wrist velocity occurred almost simultaneously with the first foot contact at 56% and 57% of KT, respectively. The novice had disparity between

Table 2. The following table describes tori's peak wrist velocity (m/s) and uke's peak COM velocity (m/s) for the forward (x), upward (y), and uke's right (z) directions. Also listed are the occurrences of each velocity as a percentage of total kuzushi/tsukuri (KT) time.

表2. 前方(X), 上方(Y), 受の右側(Z), 3方向の合成(r)における取の手首の最大速度と受の重心の最大速度, およびその時の崩し・作り局面の時点(%)を示した.

	Wrist x	Wrist y	Wrist z	Wrist r	COM x	COM y	COM z	COM r
Advanced	3.05	3.41	1.95	4.54	0.64	0.15	0.44	0.78
%KT	58	55	86	56	72	94	72	72
Novice	1.23	1.66	1.25	2.02	0.36	0.2	0.38	0.47
%KT	39	35	54	41	81	100	90	90

wrist velocity and foot contact time at 41% and 33% of KT, respectively. The second highest r wrist velocity occurred near second foot contact for the advanced subject at 86% and 85% of KT, respectively. The novice, on the other hand, demonstrated disparity with the second highest wrist velocity occurring at 54% of KT compared to the second foot contact at 85% of KT. Figure 2 illustrates peak r wrist velocity relative to the first and second foot contacts within the KT phase.

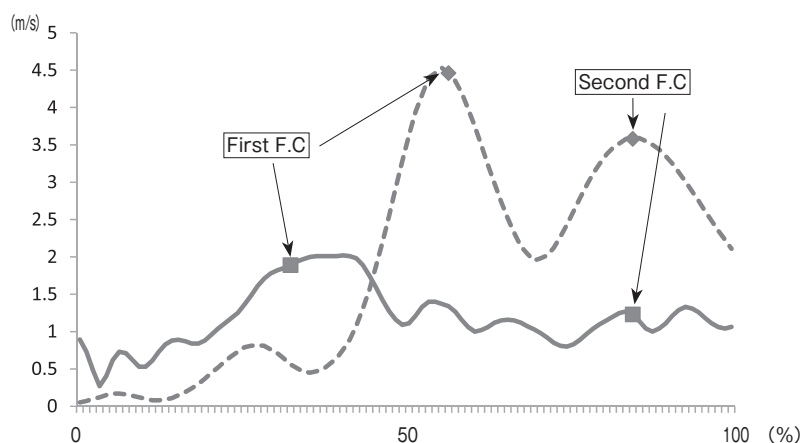


Figure 2. The graph illustrates the peak resultant (r) velocity (m/s) of the wrist for the advanced player (dashed line) and the novice player (solid line). Markers also describe the first and second foot contact for each subject.

図2. 熟練者と非熟練者の手首の最大合成速度. グラフ上のマークは最初の足の床接地と2歩目の足の床接地を表している.

Discussion

It was the intention of this study to provide preliminary data for analyzing the relationship between *tori's* pulling force and ground force during the *kuzushi/tsukuri* (KT) phase of the throw *seio-nage*. It was hypothesized that *tori's* pulling force would be directly related to ground reaction forces (GRF) created by the feet. While GRF was not measured in this study, it was assumed that foot contact with the ground created GRF necessary to create pulling force.

The results indicated differences in pulling force between skill level. The advanced subject demonstrated larger peak wrist velocity in all three directions of pull. The directions of pull were the same between subjects with both pulling *uke* forward, to the right, and upward. *Uke's* peak COM velocity was also larger for the advanced subject and occurred in the same directions as the wrist velocities for both subjects. For the most part, the results were predictable as they indicated that both subjects were executing the same throwing technique but with different pulling force magnitudes. It was interesting, however, that both subjects executed the KT phase at similar speeds (1.15 s for advanced versus 1.16 s for novice) . Thus, the novice subject was able to execute the KT phase with the same speed as the advanced subject but with much less force from the pulling hand and less force onto the body of *uke*.

There was also a timing difference between foot contact and peak wrist velocity between skill level. The advanced subject created the highest and second highest wrist velocities almost simultaneously with both their first and second foot contacts, respectively. The novice player, on the other hand, demonstrated a time difference between both foot contacts and the two highest wrist velocities. The highest wrist velocity occurred later than the first foot contact, while the second highest wrist velocity occurred much sooner than the second foot contact. Assuming that the advanced subject is mechanically more efficient than the novice subject, the data indicate that there is a link between the timing of foot contact (GRF) and wrist velocity (pulling force) . Because both wrist velocities and COM velocities for *uke* were much larger for the advanced subject, it can be assumed that the GRF plays a key role in the generation of pulling force.

There is also an indication that a greater time difference between GRF and wrist velocity can be detrimental to an effective pulling force. As stated earlier the advanced subject was able to create the highest wrist velocities at the point of contact for both feet, while the novice demonstrated disparities between foot contact and wrist velocity for both feet. Thus, the timing of GRF production and how it may contribute to pulling force looks to be an advanced skill. In terms of phase analysis, the first foot contact is likely responsible for the function of *kuzushi* or breaking *uke's* balance. Since the novice subject demonstrated a lag between the first foot contact and peak wrist velocity, it is possible that the subject has not developed the skill to time GRF properly with pulling force and effectively execute *kuzushi*.

Conclusion

An obvious limitation to this study is the lack of GRF data from a force plate. Direct GRF measurements would determine whether or not the novice subject's deficiencies in pulling force stem from timing issues, deficient GRF production, or a combination of both. Thus, future studies should incorporate GRF measurements from a force plate in conjunction with kinematic analysis. Overall, this study demonstrated possible a link in the timing of GRF and pulling force generated by *tori* during KT. Likewise, this timing can be considered a possible indicator of skill level and precursor to an effective throw.

References

- Clauser, C.E., McConville, J.T., and Young J.W. (1969) : Weight, volume, and centre of mass of segments of the human body. *AMRL Technical Report (TR-69-70)* . Wright Patterson Air Force Base, OH.
- Harter, R.A. and Bates, B.T. (1985) : Kinematic and temporal characteristics of selected judo hip throws. In J. Teraud and J.N. Barham (Eds.) , *Biomechanics in Sport II. Proceedings of ISBS, Del Mar, CA, Research Center for Sports* (pp. 141-150) .
- Imamura, R.T., Hreljac, A., Escamilla, R.F., & Edwards, W.B. (2006) : Three dimensional analysis of center of mass for three different judo throwing techniques. *Journal of Sport Science and Medicine*, CSSI, 122-131 (On-line) . Available: <http://www.jssm.org>
- Imamura, R.T., Iteya, M., Hreljac, A., & Escamilla, R.F. (2006) : *A kinematic comparison of the Judo Throw harai-goshi during competitive and non-Competitive Conditions – a case study*. Manuscript submitted for publication.
- Ishii, T., Komata, K., Okada, H., Kubota, H., & Muraki, Y. (2005) : *A biomechanical investigation of kuzushi of osoto-gari in kano cup international competition*. Paper presented at the World Judo Championship Research Symposium, Cairo, Egypt.
- Kano, J. (1986) : *Kodokan judo*. Kodansha International, Tokyo.
- Pucsok, J.M., Nelson, K., and Ng, E.D. (2001) : A kinetic and kinematic analysis of the harai-goshi judo technique. *Acta Physiologica Hungarica*, 88 (3-4) , 271-280
- Tezuka, M., Funk, S., Purcell, M., and Adrian, M. (1983) : Kinetic Analysis of judo technique. In H. Matsui & K. Kobayashi, *Biomechanics, VIII-B* (pp 869-875) . Champaign, IL: Human Kinetics.