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Analysis of patterns of response to *kuzushi* in eight drections based on plantar pressure and reaction movement

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

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Summary

Background: The purpose of this study was to examine immediate changes in plantar pressure of the eight directions of Kuzushi for top-ranked judo players.

Material/Methods: Subjects were two male judo players who had experienced special training to advance their skills. *Tori* was then instructed to perform *kuzushi* very quickly in any of the 8 directions while the subject was instructed to respond against *kuzushi*. The maximum plantar pressure (MPP), the center of plantar pressure (COP) and the mean plantar pressure (m-PP) at the reaction time were analyzed. Movements were also simultaneously recorded using a video camera.

Results: *Uke* responds to a quick *kuzushi* attempt by either 1) *tai-sabaki* (repositioning of body movement) or 2) reflex (stepping reaction). Especially for *kuzushi* in the back direction, Subject A maintained balance by pulling the left foot back, and thus the COP (R4.4%, 55.6%) and the m-PP (left ball of the foot; 8.2±8.4 N/cm^2, right heel; 3.4±3.3 N/cm^2) showed high values. Subject B maintained balance by pulling the right foot back, and the COP (R19.1%, 30.6%) and the m-PP (outside right heel; 7.4±6.2 N/cm^2, inside right heel; 8.2±7.6 N/cm^2) showed high values.

Conclusions: The present study has revealed that *uke* responds to *kuzushi* by either *tai-sabaki* or reflex. We may be able to develop more effective ways of applying technique against different opponents by seeking effective *kuzushi*, *tuskuri* and *kake* techniques based on these findings.

Key words: **plantar pressure • judo • *kuzushi* (balance-breaking) • reaction**

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BACKGROUND

Shizen-hontai (natural posture) in Judo allows quick response to *kuzushi*, an attempt to unbalance the opponent. The posture corresponds to the "basic dynamic posture" described by Howorth [1], which enables the quickest response during physical movement. Judo players are required to respond quickly to the opponent's movement evenly in all directions through 360 degrees. A previous study has demonstrated that maintaining the center of gravity at 45% of the foot length from the heel moderately shortens the response time required to move in the front and back direction [2], which can be achieved with *shizen-hontai*.

When the two players are gripping each other, a certain level of muscle tone is generated by such neural reflexes as tonic labyrinthine reflex, tonic neck reflex, supporting reflex and extension reflex, based on the relative positions of the head, body trunk and four limbs, enabling a quick response to the opponent's *kuzushi* attempt. When the opponent is making a quick movement, skilled players attempt to return to the original posture by reflex or by learning to minimize deviation of the center of gravity from the basal surface. A previous study on the balance ability of judo players [3] has shown that they maintain balance against instantaneous impact by making one step forward from *shizen-hontai* and lowering the hip to broaden the right and left basal surfaces, thereby dispersing anteroposterior impact to the right-left direction.

The changes in plantar pressure during response to the *kuzushi* attempt while considering the human body as a rigid frame have been examined in one study [4]; however, the effects of human reflex or *tai-sabaki* (body shifting) in Judo were not considered. In actual *randori* (free practice), when *tori*, the judoka performing a technique, attempts to unbalance his or her opponent in any direction, *uke*, the judo player against which the attack is directed, is not always able to bear weight on the intended part of the body. Another study analyzing plantar pressure during response to the *kuzushi* attempt using a force plate failed to reveal plantar pressure distribution [5]. In separate research [6], the plantar pressure distribution during throwing techniques was closely examined in relation to the difference in skill, but not in the case of *uke*.

In the present study, we analyzed the relationship between the movement of *uke* responding to a quick *kuzushi* attempt of *tori* and plantar pressure, and report here two patterns of response.

MATERIAL AND METHODS

Subjects

The study subjects were 2 judo players who have won the highest prizes in top-level competitions in Japan: judo player A (*uke*) in the 73.0 kg weight class, 4th dan, with a height of 166.0 cm and weight of 77.0 kg; and judo player B (*tori*) in the 81.0 kg weight class, 5th dan, with a height of 179.0 cm and weight of 83.0 kg. In study *tori* function was performed by the judo player, who the nomination for the 5th dan received in Kodokan Judo.

Methods of measurement

Plantar pressure was measured with the Pressure Measuring System (T&T medilogic). The subjects were asked beforehand to wear shoes with sensor-equipped soles. Each of the right and left insoles placed in the shoes were equipped with 64 pressure sensors for transmitting the measurement data of subjects to a receiver at a sampling frequency of 60 Hz on a real-time basis. The obtained data were analyzed by the computer.

On the floor, 8 lines were drawn at 60 cm from a central position in the front, back, left, right, left front corner, right front corner, left back corner and right back corner directions. The subject was instructed to stand at the center of the lines in a *shizen-hontai* and *tori* stood in front of the subject. They were then instructed to grip each other, with the same grip used by both judo players (Figure 1). *Tori* was then instructed to perform *kuzushi* very quickly in any of the 8 directions while the subject was instructed to respond against *kuzushi*. The subject was instructed not to step outside of any of the lines drawn at 60 cm from the center. During the *kuzushi* attempts, the subject's movement was recorded with video recorders from 4 directions. To synchronize the timing of input from the sensors and that of the video recordings, LED lamps were placed within the camera frames, a switch for the LED lamps was pushed by the sole of the subject's foot before the start of the test, and the time of signal input to the plantar pressure sensors was synchronized with that of lighting of the LED lamps.

Methods of analysis

Comparison of movement against kuzushi in 8 directions and maximum plantar pressure (MPP)

A time point at which *uke* responded to the *kuzushi* attempt of *tori* and both of the judo players became motionless on the video screen, or a time point when their internal force reached equilibrium, was defined as the time point at which *uke* responded to the *kuzushi* attempt of *tori*. The MPP in the right and left feet and the positions of the sensors yielding MPP at the time point were recorded.

Center of plantar pressure(COP)

The COP on the basal surface was calculated from the plantar pressures in the right and left feet. The position of the COP was expressed as a percentage of the anteroposterior distance from the heel to the COP when the foot length was considered as 100%, and a percentage of the distance in the left-right direction from the midline between the lateral sides of both feet to the COP, with 50% as the maximum value.

Comparison of mean plantar pressure (m-PP) in the forefoot, rear foot, medial and lateral portions of the foot.

The 64 plantar pressure sensors were divided into the following categories and the mean pressures in each category were compared (Figure 2).

Lateral forefoot: LFF (1, 4, 5, 6, 9, 10, 11, 15, 16, 17, 21, 22, 23, 24, 28, 29, 30, 31, 34, 35, 36 and 37).

Medial forefoot: MFF (2, 3, 7, 8, 12, 13, 14, 18, 19, 20, 25, 26, 27, 32, 33 and 38).

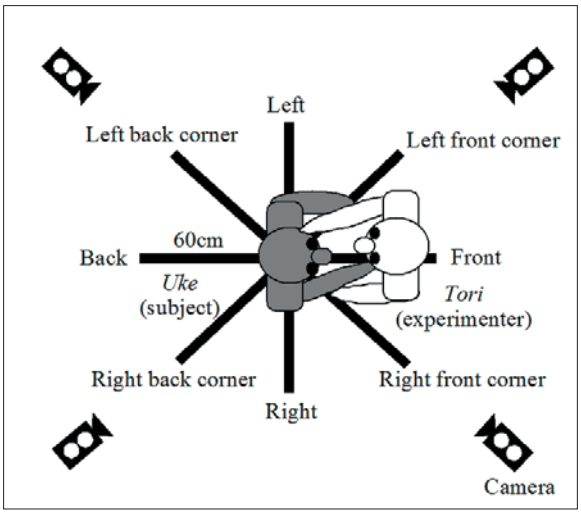

Figure 1. Experimental setup.

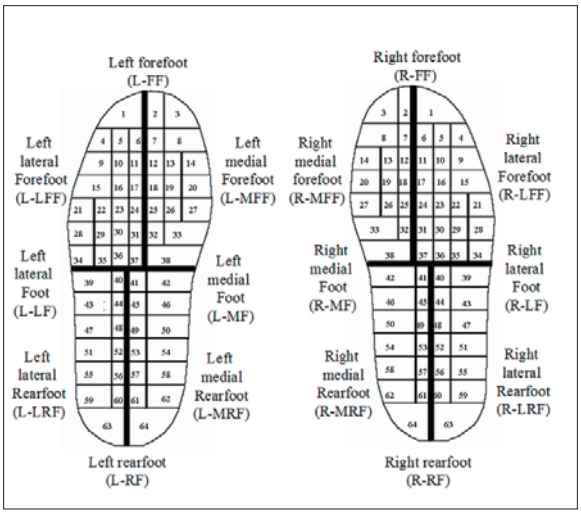

Figure 2. Categories of the planter pressure sensors.

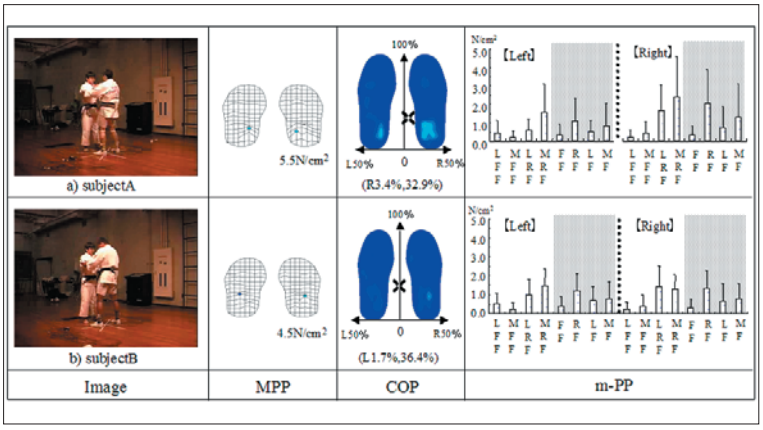

Figure 3. Shizen-hontai: MPP/COP/m-PP.

Lateral rear foot: LRF (39, 40, 43, 44, 47, 48, 51, 52, 55, 56, 59, 60 and 63).

Medial rear foot: MRF (41, 42, 45, 46, 49, 50, 53, 54, 57, 58, 61, 62 and 64).

Forefoot: FF(sensors in the anterior medial and anterior lateral portions).

Rear foot: RF (sensors in the posterior medial and posterior lateral portions).

Lateral foot: LF (sensors in the anterior lateral and posterior lateral portions)

Medial foot: MF(sensors in the anterior medial and posterior medical portions).

Results

Shizen-hontai (Figure 3)

A similar tendency was observed in both subjects A and B with respect to MPP, COP, and m-PP. Analysis of the m-PP in *shizen-hontai* showed that both subjects were bearing weight on the posterior portion of the foot.

***Kuzushi* in the front direction** (Figure 4)

Subject A showed high values of MPP in the right hallux (31.9 N/cm^2) and surrounding areas, with the COP located almost at the midpoint in the left-right direction. Analysis of the mean plantar pressures showed that the subject was bearing weight on the anterior portions of both feet (3.7±6.0 N/cm^2 in the right and 3.0±3.2 N/cm^2 in the left). A still image taken at this time point showed that the subject placed both feet parallel to each other.

Subject B, as did subject A, revealed high values of MPP in the right hallux (22.8 N/cm^2) and surrounding areas. The COP was located 14.7% to the right from the midline. Analysis of the m-PP showed that the subject was bearing weight on the MFF (4.9±5.9 N/cm^2) and FF (3.4±4.2 N/cm^2) portions of the right foot, with almost no weight borne on the left foot. A still image taken at this time point showed that the subject stepped forward substantially with the right foot to maintain stability.

***Kuzushi* in the back direction** (Figure 5)

Subject A demonstrated high values of MPP in the ball of the left (21.8 N/cm^2) and surrounding areas, with the COP located 4.4% to the right from the midline in the left-right

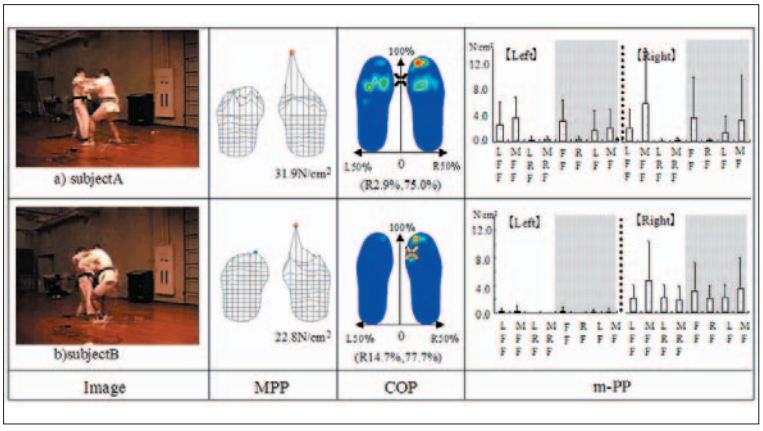

Figure 4. Front: MPP/COP/m-PP.

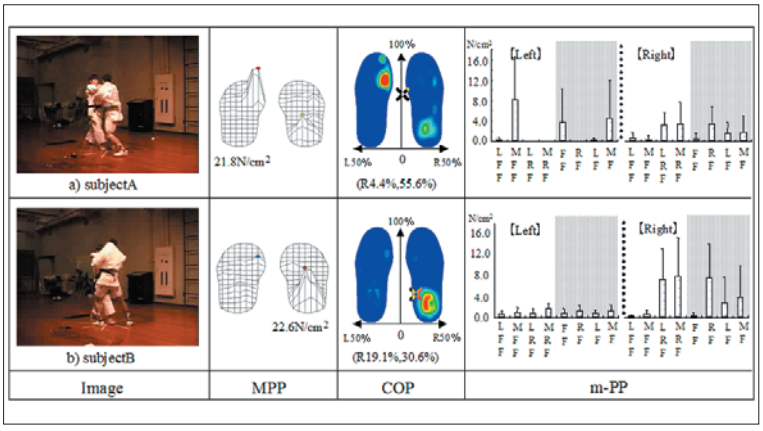

Figure 5. Back: MPP/COP/m-PP.

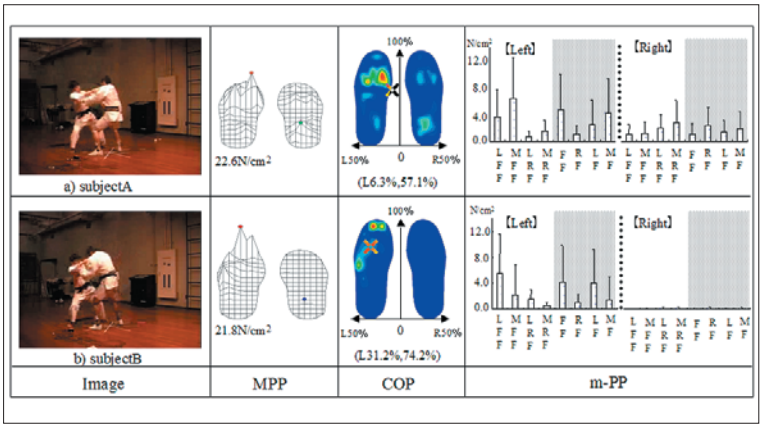

Figure 6. Left: MPP/COP/m-PP.

direction and 55.6% in the anteroposterior direction. High values of m-PP were recorded in the MFF of the left foot (8.2±8.4 N/cm^2) and the RF of the right (3.4±3.3 N/cm^2). A still image showed that the subject pulled the left foot back substantially to maintain balance.

Subject B, unlike subject A, exhibited the highest value of MPP in the right heel (22.6 N/cm^2) and surrounding areas. The COP was located 19.1% to the right and 30.6% in the anteroposterior direction, showing a shift toward the right posterior direction. High values of m-PP were recorded in the LRF (7.4±6.2 N/cm^2) and MRF (8.2±7.6 N/cm^2) portions of the right foot. A still image showed that the subject, contrary to subject A, pulled the right foot back substantially.

***Kuzushi* in the left direction** (Figure 6)

Subject A revealed high values of MPP in the ball of the left (22.6 N/cm^2) and surrounding areas. The COP was located 6.7% to the left, showing no substantial shift towards the left. High values of the m-PP were recorded in the MFF of the left (6.4±6.1 N/cm^2) and the MRF portion of the right (2.7±3.2 N/cm^2). A still image showed that the subject stepped forward with the left foot to maintain balance while keeping the upper body aligned in a vertical direction, with no sign of significant unbalance.

Subject B had high values of MPP in the left third toe (21.8 N/cm^2) and surrounding areas. The COP was located 31.2% to the left, showing a substantial shift toward the left.

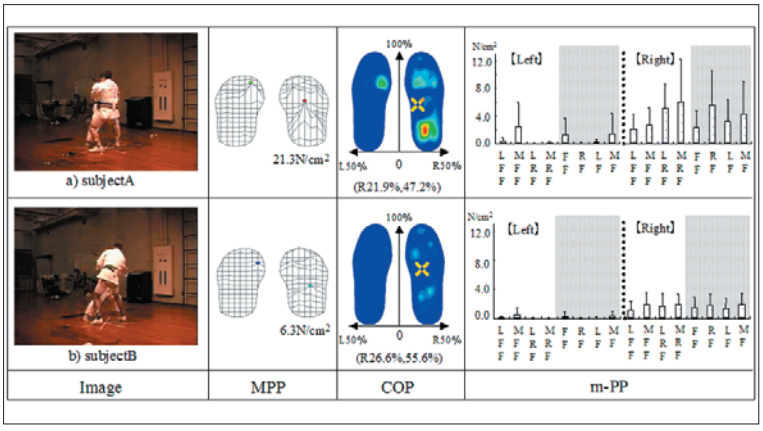

Figure 7. Right: MPP/COP/m-PP.

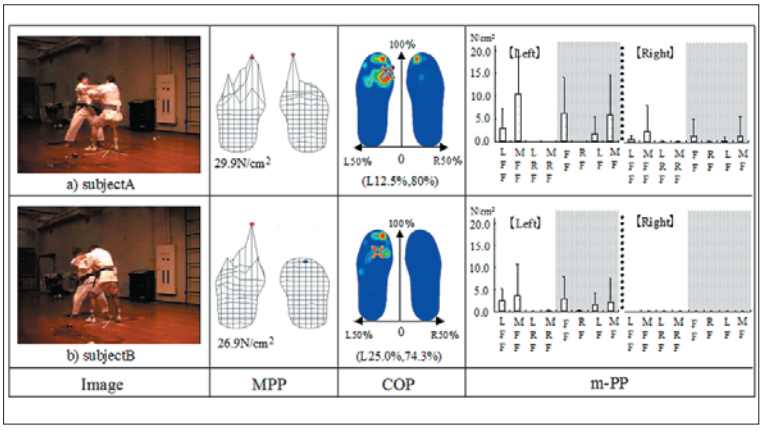

Figure 8. Left front corner: MPP/COP/m-PP.

m-PP was high in the LFF portion of the left (5.5±6.1 N/cm^2), with no apparent evidence of weight load on the right foot. A still image showed that the subject stepped forward with the left foot forward in response to *kuzushi* in the left direction, resulting in a shift of the upper body toward the left.

Kuzushi in the right direction (Figue 7)

Subject A demonstrated high values of MPP in the right heel (21.3 N/cm^2) and surrounding areas, with the COP located 21.9% to the right and 47.2% in the anteroposterior direction. High values of m-PP were recorded in the LRF (6.1±6.5 N/cm^2) and MRF (5.2±3.7 N/cm^2) portions of the right and the MFF portion of the left (2.5±3.4 N/cm^2). A still image showed that the subject stepped forward with the right foot to maintain balance, with no sign of significant unbalance in the upper body.

Subject B had high values of MPP in the right heel (6.3 N/cm^2) and surrounding areas, with the COP located 26.6% to the right and 55.6% in the anteroposterior direction. M-PP in the right foot were 1.5±1.5 N/cm^2 in the FF portion, 1.9±1.5 N/cm^2 in the RF portion, 1.4±1.5 N/cm^2 in the LF portion, and 2.0±1.5 N/cm^2 in the MF portion, showing almost even weight load on the 4 portions. In contrast, no apparent evidence of weight load was observed on the left foot. A still image showed that the subject stepped forward with the right foot in response to *kuzushi* in the right direction to maintain balance, resulting in a shift of the upper body toward the right.

***Kuzushi* in the left front corner direction** (Figure 8)

Subject A had high values of MPP in the ball of the left big toe (29.9 N/cm^2) and surrounding areas, with the COP located 12.5% to the left and 80% in the anteroposterior direction. High values of m-PP were recorded in the MFF portion of the left (10.5±9.7 N/cm^2) and the MFF portion of the right (2.5±9.6 N/cm^2). A still image showed that the subject stepped forward with the left foot to maintain balance while maintaining vertical alignment of the upper body, with no sign of significant unbalance.

Subject B showed high values of MPP in the ball of the left big toe (26.9 N/cm^2) and surrounding areas, with the COP located 25.0% to the left and 74.3% in the anteroposterior direction. m-PP was high in the MFF portion of the left (3.6±7.0 N/cm^2), with no apparent evidence of weight load on the right foot. A still image showed that the subject stepped forward with the left foot toward the left anterior direction, with the upper body also shifted toward the same direction.

***Kuzushi* in the right front corner direction** (Figure 9)

Subject A revealed high values of maximum plantar pressure in the ball of the right big toe (40.2 N/cm^2) and surrounding areas, with the COP located 21.8% to the right and 71.4% in the anteroposterior direction. Mean plantar pressure was high in the anterior medial portion of the right foot (10.9±12.0 N/cm^2), with no apparent evidence

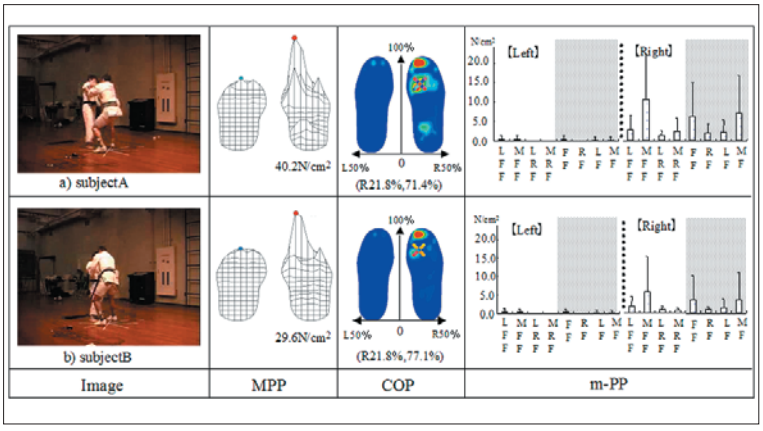

Figure 9. Right front corner: MPP/COP/m-PP.

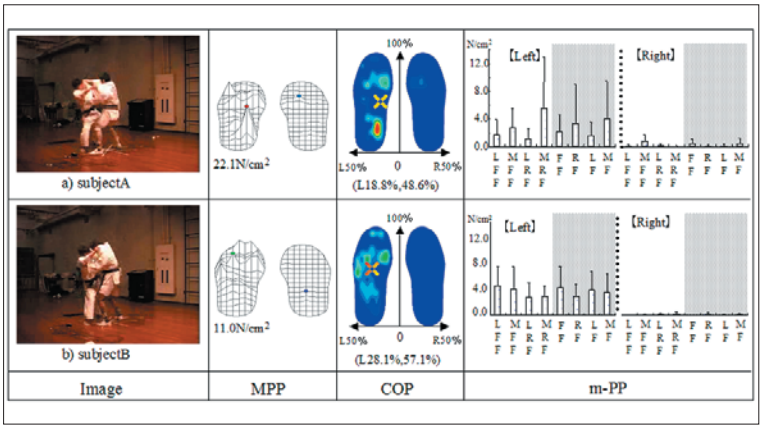

Figure 10. Left back corner: MPP/COP/m-PP.

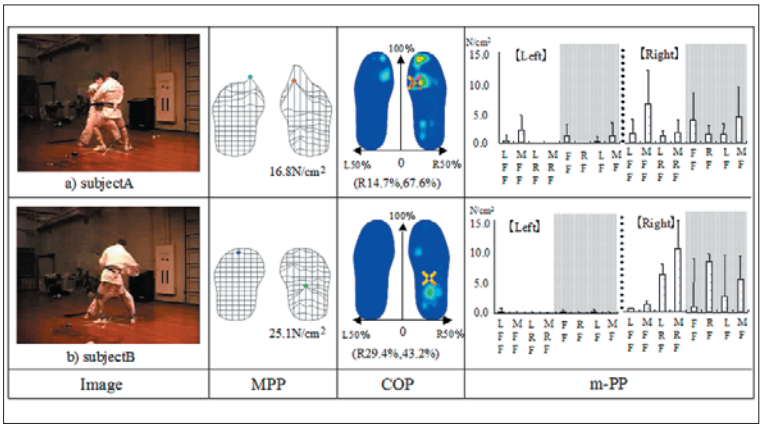

Figure 11. Right back corner: MPP/COP/m-PP.

of weight load on the left foot. A still image showed that the subject stepped forward with the right foot to maintain balance while maintaining vertical alignment of the upper body, with no sign of significant unbalance.

Subject B exhibited high values of MPP in the right big toe (29.6 N/cm^2) and surrounding areas, with the COP located 21.8% to the right and 77.1% in the anteroposterior direction. m-PP was high in the MFF portion of the right (5.9±9.2 N/cm^2), with no apparent evidence of weight load on the left foot. A still image showed that the subject stepped forward with the right foot to maintain balance and the upper body shifted toward the right anterior direction.

***Kuzushi* in the left back corner direction** (Figure 10)

Subject A had high values of MPP in the MF portion of the left heel (22.1 N/cm^2) and surrounding areas, with the COP located 18.8% to the left and 48.6% in the anteroposterior direction. High values of m-PP were recorded in the MFF portion of the left (2.8±2.7 N/cm^2) and the MRF portion of the left foot (5.6±7.4 N/cm^2), with no significant weight load on the right foot. A still image showed that the subject pulled the left foot back to maintain balance, with no sign of significant unbalance in the upper body.

Subject B revealed high values of MPP in the LFF portion of the left (11.0 N/cm^2) and surrounding areas, with the COP

located 28.1% to the right and 57.1% in the anteroposterior direction. Analysis of the m-PP showed almost even weight load on the left foot, except for a slightly high load in the FF portion (4.2±3.1 N/cm^2), with no apparent evidence of weight load on the right foot. A still image showed that the subject pulled the left foot back and the upper body shifted toward the left posterior direction.

***Kuzushi* in the right back corner direction** (Figure 11)

Subject A exhibited high values of MPP in the ball of the right big toe (40.2 N/cm^2) and surrounding areas, with the COP located 14.7% to the right and 67.6% in the anteroposterior direction. m-PP was high in the MFF portion of the right (6.4±5.6 N/cm^2), with slight weight load on the MFF portion of the left foot (2.2±2.4 N/cm^2). A still image showed that the subject pulled the right foot back to maintain balance, with no sign of significant unbalance in the upper body.

Subject B showed high values of MPP in the right heel (25.1 N/cm^2) and surrounding areas, with the COP located 29.4% to the right and 43.2% in the anteroposterior direction. High values of m-PP recorded in the LRF (6.1±4.5 N/cm^2) and MRF (10.4±7.9 N/cm^2) portions of the right, with no apparent evidence of weight load on the left foot. A still image showed that the subject pulled the right foot back to maintain balance and the upper body shifted toward the right posterior direction.

Discussion

The plantar weight-bearing pattern during response to *kuzushi* in 8 directions was previously studied using a footprint method by Matsumoto et al [4]. They compared the portions of the sole contacting the ground when *uke* does not respond to the *kuzushi* attempt of *tori*, and reported that against *kuzushi* in the front direction, judo players lift the heel while shifting weight to the anterior portion of the sole, mainly in the toes and ball of the foot. A similar tendency was also observed in both subjects in the present study (Figure 4). It is reported that against *kuzushi* in the back direction, the only portion to contact the ground is the heel and the weight is placed mainly at the center of the heel. However, subject A in the present study quickly pulled the left foot back and placed weight on the ball of this foot to locate the COP at the center of the basal surface in response to *kuzushi* in the back direction (Figure 5). In contrast, subject B bore weight by pulling the right foot back while placing no significant load on the left foot, resulting in weight load on the right heel (Figure 5). Against *kuzushi* in the left direction, the LF portion of the left foot contacts the ground. This was consistent with the findings of subject B, whereas subject A placed his weight mainly on the ball of the left foot (Figure 6). Subject A appeared to attempt to maintain stability by counteracting external force by pronating the left foot and concentrating weight on the ball of this foot. Against *kuzushi* in the right direction, the heel is lifted and thereby the area contacting the ground is reduced. However, inconsistent with the previous findings, subject A placed weight mostly on the heel of the right foot, and subject B placed weight on the entire sole of the right foot (Figure 7).

The patterns of response of subjects A and B in the present study are obviously different from those of *uke* in the above-mentioned study [4]. Many of the previous studies considered *uke* as a rigid frame and did not consider reflex- or learning-mediated responses to quick *kuzushi* attempts. When a human dummy is used, the patterns of weight bearing during response to *kuzushi* in 8 directions are expected to be the same as those in the previous studies. However, since the actual practice of judo is performed by live humans, it is necessary to clarify how *uke* responds to a quick and unpredictable *kuzushi* attempt. Understanding the pattern of response of *uke* to *kuzshi* attempts and the actual status of unbalance (e.g. plantar pressure distribution in the present study) will enable development of effective *kuzushi* techniques.

The results of the present study suggest that subject A responded to the *kuzushi* attempts of *tori* by *tai-sabaki*, a repositioning the body in which complicated movement is performed reflexively via particular neural pathways established by repeated performance of the body movement. In contrast, subject B appeared to respond to the *kuzushi* attempts by reflex involving the cerebral cortex, which naturally occurs in humans. This reaction is referred to as a stepping reaction, by which an animal whose body is pushed to either side and whose center of gravity is deviated puts forward its foot on the side of deviation in order to maintain balance. When the responses of both subjects to *kuzushi* in the back direction are compared (Figure 5), subject A quickly pulled back the left foot, the pivoting foot during right-hand gripping, in order to bear weight on the ball of this foot, resulting in minimal deviation of the COP from the center. Subject B, however, quickly pulled back the right foot to bear weight, resulting in concentration of weight on the right heel and a shift of the COP toward the right foot. A comparison of the still images of both subjects showed that subject A pulled the left foot back, resulting in stabilization of the upper body that remained vertically aligned, while subject B pulled his right foot back, resulting in a shift of the upper body backward.

The present study has revealed that *uke* responds to *kuzushi* by either *tai-sabaki* (repositioning movements) or reflex (stepping reaction). Response to *kuzushi* by *tai-sabaki* is stable because the shift of the COP from the center of the basal surface is minimum and the upper part of the body remains vertically aligned, although it may not be suitable for responding to such movement as a feint because it requires large movement of the lower part of the body against a quick movement of *tori*. In contrast, response by reflex is easily predictable because a player shows a relatively common response to *kuzushi* in each direction, but it may enable a player to respond quickly to the subsequent movement since it is a quick reaction.

Although these effects may not be obtained in the actual practice of judo since different *uke* respond in different ways to the same technique performed by *tori*, it may be possible to find a suitable way of applying techniques against different *uke* by analyzing whether *uke* responds to *tori*'s technique by *tai-sabaki* or reflex.

Conclusions

We analyzed responses of 2 top-level judo players to a quick *kuzushi* attempt based on video images and plantar pressure and obtained the following findings:

1. *Uke* responds to a quick *kuzushi* attempt by either 1) *tai-sabaki* (repositioning of body movement) or 2) reflex (stepping reaction).

2. Response by *tai-sabaki* minimizes unbalance of the upper body and shift of the COP via slight flexion of the knee and resultant movement of the hip and whole lower body; however, it may not be suitable for responding to unpredictable movements such as a feint because it requires large movement.

3. Response by reflex requires a judo players to place his or her foot toward the direction in which *kuzushi* is attempted in efforts to maintain balance, and thus causes a shift of the COP toward the same direction. This may help the player to respond to unpredictable movements such as a feint because it does not cause large movement in the lower part of the body.

These findings suggest that the pattern of response to *kuzushi* is not uniform but varies among different *uke*. We may be able to develop more effective ways of applying technique against different opponents by seeking effective *kuzushi*, *tuskuri* (entry into a technique) and *kake* (completion or execution of technique) techniques based on these findings.

REFERENCES:

1. Howorth B: Dynamic posture. JAMA, 1946; 131: 1398–410
2. Katsuo F: *Kamae* posture and quickness of response movement. J J SPORTS SA, 1994; 13(6): 739–49
3. Masahiko K, Teizo K, Takaaki A et al: Analysis of balance ability of Judo players – Balance control against *kuzushi*. Research Journal of Budo, 1984; 16(1): 121–23
4. Yoshizo M, Yoshinori T, Ryozo N et al: Analysis of *kuzushi* in throwing techniques of Judo. Bulletin of the Association for the Scientific Studies on Judo, Kodokan, Report V. 1978; 31–38
5. Seiki N, Teizo K, Yoshinori T, Shunsuke Y: Study on throwing techniques of Judo – Analysis of "*kamae*" "*kuzushi*" "*tsukuri*" and "*kake*" based on plantar pressure. Research Journal of Budo, 1981; 14(1): 51–63
6. Taketo S: Biomechanical study of throwing techniques of Judo based on changes in plantar pressure – Differences in *seoi-nage* skill. Research Journal of Budo, 1985; 17(3): 18–28