BIOMECHANICAL CONSIDERATIONS OF TAKEUMA-WALKING IN WATER

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"TAKEUMA" is one of Japanese classic style of playing. Usually it is played on land, but in water, one can easier ambulate with TAKEUMA in water, for buoyancy and resistance force. The purposes of this study were to clarify biomechanical features of TAKEUMA-walking in water and to compare the motion characteristics of skilled TAKEUMA players with those of unskilled. The TAKEUMA-walking motions were recorded both in a water tank and on land. It was revealed that the body inclination to the forward direction would be a key feature of the well-trained TAKEUMA-walking, and even in unskilled subjects the relatively greater forward-inclined posture was preserved in water. It is important to handle and hold a TAKEUMA by using upper limbs, especially forearms, when walking with TAKEUMA in water.

KEY WORDS: TAKEUMA, walking in water, upper limb, lower limb, forward-incline posture.

INTRODUCTION: Walking is one of the most safety aerobic exercises, for impact forces acting at lower limb joints are smaller than the other exercises such as running, aerobic dance etc. Walking in water could be a more advantageous exercise mode if physical characteristics of water are properly utilized. TAKEUMA is one of Japanese classic style of playing (Yamamoto H. et al., 1993). Players walk with two long sticks (TAKEUMA) while their arms hold sticks and their foot are on footrests attached perpendicular to each stick at 10 to 20 cm high from the bottom. Due to its unstableness it is difficult to ambulate with TAKEUMA unless one can stabilize one's body with TAKEUMA without any support on land. In water, however, one can easily ambulate with TAKEUMA, for buoyancy and viscoelasitic characteristic of water make it easier to keep body balance (Fig.1). Therefore, greater possibility exists that even the person who can't ambulate with TAKEUMA on land might be able to do in water. The purposes of this study were to clarify biomechanical features of TAKEUMA-walking in water and to compare the motion characteristics of skilled TAKEUMA players with those of unskilled.

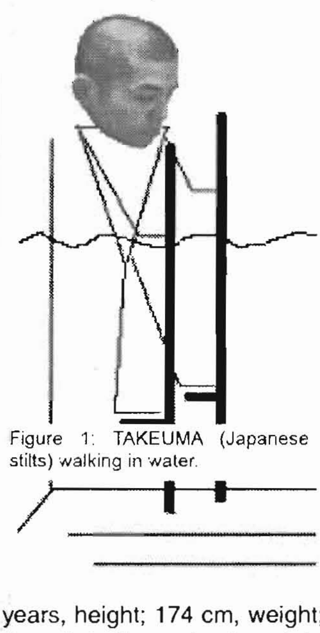
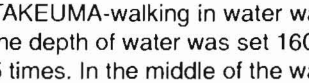


Figure 1: TAKEUMA (Japanese stilts) walking in water.



METHODS: Two healthy male subjects voluntarily participated in this study, one was skilled (age; 21 years, height; 178 cm, weight; 63 kg) at TAKEUMA, and another was unskilled (age; 22 years, height; 174 cm, weight; 77 kg). The subjects ambulated with TAKEUMA (Dai-ichi Corp. Japan) both on land and in water, and the height of footrests were set at 20cm. The TAKEUMA-walking in water was performed in a water tank (Ishikawajima Harima, Japan), and the depth of water was set 160cm.The subjects were asked to walk about 4m in the water tank 5 times. In the middle of the water tank a waterproof force plate (KISTLER9523A12) was set to measure ground reaction forces. Two CCD Cameras (HZF9060, 30 Hz) were placed at the subject's left front and left back to analyze the TAKEUMA-walking motion. The analysis points on the body were 5 points: the waist; the greater trochanter; the knee region; the ankle; and the toe. The motion analysis was done using the sagital plane. The electromyographic (EMG) activities were recorded by using a pair of surface electrodes (Ag-AgCl, 8 mm diameter, center to center distance of 1.5 cm) from the following muscles, M. triceps brachii (Tri), M. flexor (Flex), M. extensor (Ext) and those of lower limb was M. gastrocnemius (MG), M. tibialis anterior (TA), M. rectus femoris (RF), M. biceps femoris (BF). The EMG signals were amplified by using a multi-channel-amplifier. Both the EMG and ground reaction force signals were digitized at a sampling frequency of 1 kHz for later analysis.

RESULTS AND DISCUSSIONS: Kinematics: *(1)TAKEUMA-walking for the "skilled":* In the water tank, the waist was always ahead of the greater trochanter, knee region, ankle, and toe (Fig.2), but later, knee region was ahead of the waist. The changes of leg's movement were little, but that swelled from middle stage. This was because movements were lessened by opposition of water. The characteristics were forward-bent of both the upper limb and the lower limb, and the step was shorter than on the ground. On the ground, the waist was always ahead of the greater trochanter and ankle (Fig.3). And the knee region was ahead of the toe before his leg touched the floor, but toe was ahead of that at the moment his leg touched. Leg's movement clearly swelled at the end. This was because there was no opposition of water, and because of quickly movement of legs at the end. The characteristics were forward-bent of upper limb and lower limb, the longer step, and swelling of leg's movement at the end. Otherwise the body inclination on the ground was smaller than that in the water tank.
(2)TAKEUMA-walking for the "unskilled": In the water tank, the waist was always ahead of the greater trochanter and ankle (Fig.4). The knee region tended to be ahead of the waist and the greater trochanter, and at the moment his leg touched the floor, the toe was ahead of that, too. The characteristics were separation of TAKEUMA and the upper limb, and the state of the small tilt of upper limb. The walking was relatively stable. On the ground, the knee region and toe were almost ahead of the waist (Fig.5).The tilt of the line which waist to the greater trochanter was smallest, also that inclined to back by the case. The characteristics were separation of TAKEUMA and the upper limb, also, the state which the body stood up more than in water tank. In the case of movement of legs, that was the same as "skilled"'s tendency both in the water tank and on the ground. In the water tank, waking was more stable in a forward-bent posture than that on the ground because of buoyancy's or opposition's effect. Therefore, it suggested that TAKEUMA-walking in the water tank would be one of the methods to practice which used characteristics of water.
EMG activities: For the skilled the EMG activities in lower limb were dramatically reduced, whereas those in upper arm muscles were unchanged or rather increased during walking in water. (Fig.6)These results were caused mostly from the reduced weights due to buoyancy and greater resistance force in water. For the unskilled, the EMG activities were generally greater and variable, suggesting that muscular activities in general were not well coordinated. (Fig.7)
Push-off force: At TAKEUMA-walking in water, the "skilled" subject's vertical components of the push-off force decreased to under 30%, and the "unskilled" subject's ones decreased to under 25%, compared to that on land. Moreover, considering the activities of lower limb- muscles were reduced, TAKEUMA-walking in water is an exercise with low responsibility to the lower limb.
Overall, the body inclination to the forward direction would be a key feature of the well-trained TAKEUMA-walking. It might be possible even in a naïve TAKEUMA-walker to make a body incline when walking with TAKEUMA in water. The reduced weight and greater resistance force could help to make balance on TAKEUMA in water, which in turn might make it possible to have fun and good aerobic exercise with TAKEUMA even for naive TAKEUMA walkers in water.

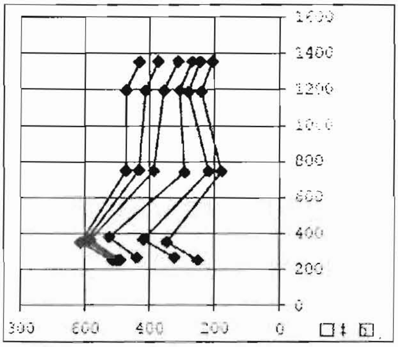


Figure 2: Walking in water for the "skilled".

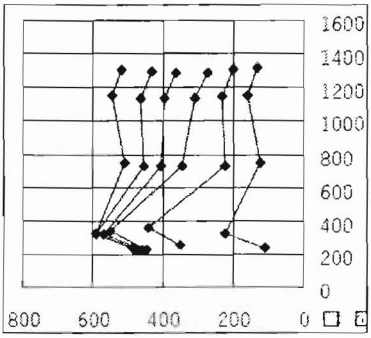


Figure 3: Walking on land for the "skilled"

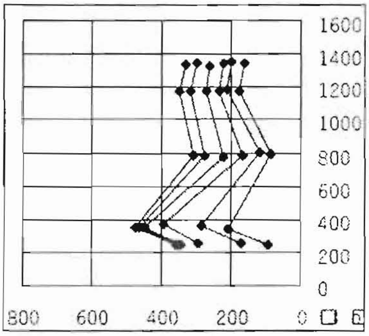


Figure 4: Walking in water for the "unskilled"

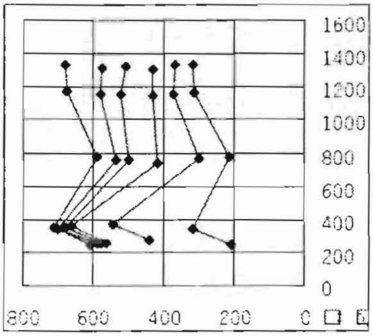


Figure 5: Walking on land for the "unskilled".

CONCLUSION: To walk with TAKEUMA in the water, it was important to handle and hold TAKEUMA by using the upper limb especially the forearm. TAKEUMA-walking in water provided a low load to the lower limb. The TAKEUMA-walking in water was firmer in a forward-incline posture than doing on land. Therefore, it is concluded that TAKEUMA-walking in water might be used for training with the advantages of water.

REFERENCE:

Yamamoto, H., Azuma, A., Yamamoto, S.-i., Saikawa, Y., Kudoh, Y., & Kawahara, K. (1993). A case study of Takeuma practices in pool. Fac. of Educ., Kanazawa Univ., Studies in Curriculum Research And Development ,29, 85-90.

water	stance phase X	stance phase SD	stance phase MAX	stance phase MIN	swing phase X	swing phase SD	swing phase MAX	swing phase MIN	1cycle X	1cycle SD	1cycle MAX	1cycle MIN
Tri	5.35	0.86	114.59	0.00	8.61	0.92	115.88	0.00	6.86	0.99	115.88	0.00
Ext	20.63	8.76	284.64	0.00	26.66	2.85	159.99	0.00	22.77	6.71	284.64	0.00
Flex	4.02	1.03	117.11	0.00	6.63	0.96	111.32	0.00	5.10	1.17	117.11	0.00
BF	2.66	0.57	42.47	0.00	1.99	0.37	37.65	0.00	2.35	0.34	42.47	0.00
RF	3.55	0.75	113.37	0.02	3.65	1.13	254.06	0.00	3.64	0.84	254.06	0.00
TA	6.27	5.20	81.88	0.00	12.01	2.90	117.75	0.00	8.48	4.34	117.75	0.00
MG	5.99	1.89	110.61	0.00	1.86	0.49	85.43	0.00	4.19	0.90	110.61	0.00
land	**X**	**SD**	**MAX**	**MIN**	**X**	**SD**	**MAX**	**MIN**	**X**	**SD**	**MAX**	**MIN**
Tri	13.21	2.60	143.68	0.01	9.39	1.66	93.76	0.02	12.21	2.07	143.68	0.01
Ext	6.73	1.35	89.00	0.01	5.64	0.93	32.39	0.03	6.41	1.16	89.00	0.01
Flex	2.05	0.25	21.03	0.00	2.74	0.22	29.15	0.00	2.22	0.22	29.15	0.00
BF	4.80	1.80	78.57	0.01	7.24	0.75	65.97	0.01	5.50	1.43	78.57	0.01
RF	10.03	2.03	120.38	0.01	5.54	1.61	51.79	0.01	8.81	1.95	120.38	0.01
TA	11.98	4.28	196.90	0.00	9.01	1.24	89.12	0.00	11.25	3.51	196.90	0.00
MG	32.62	2.08	365.34	0.02	22.75	2.67	266.28	0.02	29.95	1.20	365.34	0.02

Figure 6: EMG of TAKEUMA walking for the "skilled". **(pV)**

water	stance phase X	stance phase SD	stance phase MAX	stance phase MIN	swing phase X	swing phase SD	swing phase MAX	swing phase MIN	1cycle X	1cycle SD	1cycle MAX	1cycle MIN
Tri	10.59	3.50	178.50	0.00	11.19	4.07	131.86	0.66	10.83	3.64	178.50	0.00
Ext	14.95	3.22	190.10	0.00	20.59	3.28	151.35	0.01	16.78	3.02	190.10	0.00
Flex	12.52	1.91	154.78	0.00	13.55	3.47	126.49	0.03	12.85	2.29	154.78	0.00
BF	12.04	1.03	127.03	0.00	5.92	2.20	60.02	0.02	10.10	1.25	127.03	0.00
RF	4.33	0.68	115.34	0.00	2.88	0.63	20.46	0.00	3.84	0.61	115.34	0.00
TA	4.83	0.96	75.21	0.01	3.94	1.33	48.78	0.01	4.56	0.89	75.21	0.01
MG	9.31	2.02	161.41	0.01	4.40	0.66	110.78	0.00	7.71	1.42	161.41	0.00
land	**X**	**SD**	**MAX**	**MIN**	**X**	**SD**	**MAX**	**MIN**	**X**	**SD**	**MAX**	**MIN**
Tri	10.50	2.28	186.51	0.01	13.85	3.55	111.27	0.21	11.60	2.72	186.51	0.01
Ext	31.40	6.41	219.02	0.01	28.87	7.18	270.88	0.01	30.24	5.36	270.88	0.01
Flex	23.22	6.67	317.94	0.01	30.69	8.31	238.70	0.18	25.76	6.75	317.94	0.01
BF	25.02	3.47	194.58	0.00	5.13	1.33	72.20	0.00	18.42	1.48	194.58	0.00
RF	8.84	0.21	79.41	0.01	3.59	1.27	58.51	0.01	7.14	0.55	79.41	0.01
TA	14.50	4.72	147.61	0.01	6.33	2.11	148.28	0.02	11.59	2.84	148.28	0.01
MG	60.62	5.71	669.12	0.01	18.74	12.23	591.88	0.01	46.94	3.19	669.12	0.01

Figure 7: EMG of TAKEUMA walking for the "unskilled". **(pV)**