KINEMATIC AND DYNAMIC ANALYSIS OF THE 'MAWASHI GHERI'

RUDY ANDRIES; VAN LEEMPUTTE M; NULENS I; DESLOOVERE K

FACULTY OF PHYSICAL EDUCATIONAND FYSIOTHERAPIE, KU LEUVEN
HEVERLEE, BELGIUM.

INTRODUCTION

The complete determination of motion in space requires the definition of local reference frames (Berme, Capozzo and Meglan 1990). However, the calibration of coordinate systems within each segment is time consumming and presumes the use of at least three markers pro segment staying visible all the time. Most likely, these facts are among the reasons why three-dimensional motion analyses of complex movements are seldom used as a service tool to teachers in the field.

This study explores the possibilities to infer didactical usefull information for teaching the 'Mawashi-Gheri', a complex sidewards kicking movement in karate (fig. 1), by means of a simplified 3D-analysis.

METHODS

More precisely, the 'kihon'-version of the 'Mawashi-Gheri' with the right foot at 'jodan'-level was investigated. This is the execution of the movement emphasing the technical characteristics and dealing the hit to the head of an imaginary person.

Two advanced adults, two advanced children, two beginning children and one expert performed the technique several times.

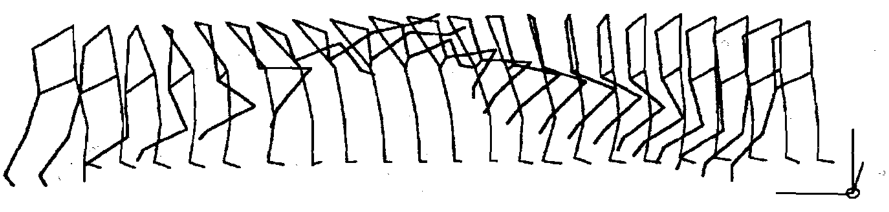


Fig. 1 : Stick-sequence of the 'Mawashi Gheri'.

Kinematic data were acquired using a semi-automatic three dimensional motion analysis system (Vicon, by Oxford Metrics). Intentionally, only ten retro-reflective markers have been used in order to reconstruct this kicking movement. They were attached to the feet, ankles, knees, hips and shoulders of the subjects according to the directives given by Plagenhoef (1971).

Raw video data were sampled at 60 Hz and processed automatically to get the three-dimensional coordinates. Missing data were interpolated by means of the free cubic spline method.

In a next step, local reference frames were defined, following the assumptions that :

1) the knee and ankle joints are revolute joints with there axes perpendicular to respectively the plane thigh-shank and the plane shank-foot (an assumption impliedly made in 2D-analyses).

2) the hip is a socket-joint with the flexion-extention axis along the interconnection of both hip markers.

These assumptions were made to offer an approximated describtion of the joint angles.

Finally, model parameters (Hanavan 1964) were employed to estimate the position of the centre of mass of the **feet,shanks,thighs** and **trunk.The** velocity of these points along with the angular velocity was derived using the **nummerical** smoothing and differentiation method outlined by Usui (1982).

Dynamic data were acquired using a Kistler-platform **configurated** to measure the force in three dimensions with three analog output **channels** at a sampling rate of 600 Hz.

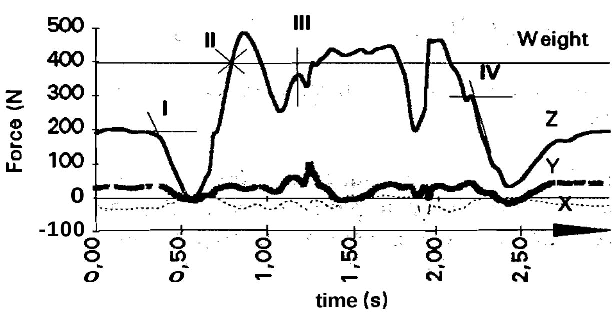
These data were filtered digitally and integrated twice using Simpson's Method.

In the tendency to avoid any restrictions to be posed on the movement (including the width of the standing base) only the left foot had to be placed on the platform. This caused an initial value problem since the velocity of the body's centre of gravity is **non** zero at the instant the right foot leaves the surface. This problem was solved accepting the supposition that the total displacement of the centre of mass from the beginning of the one-sided support (OSS) till the end of this support is zero. The **truthfullness** of this assumption was checked by comparing the position of both feet and the posture of the body at both instants.

RESULTS

For each subject the best trial was selected and graphs of the displacement and velocity of the total centre of gravity (CG) and of the segmental centres of mass as well as the graphs of angular displacement and angular velocity of the shoulders, pelvis. For each subject the best trial was selected and graphs of the displacement and velocity feet. ankle and knees were plotted on a same timebase. A selection of these graphs is depicted in the figures 2 to 6.

Out of these time courses 33 describtive parameters were selected (table 1).



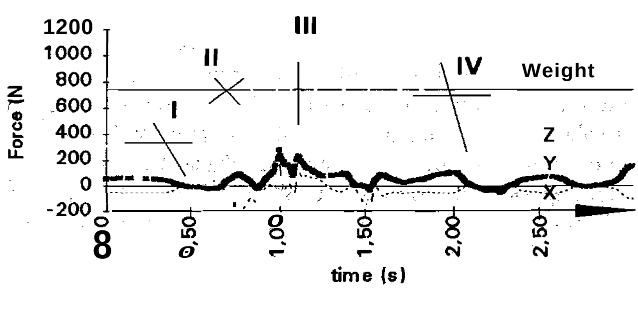
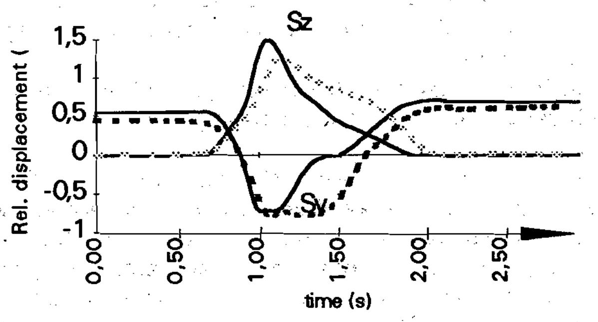


Fig. 2 :Force-time curves of the **Mawashi-Geri** performed by a beginning **child** (left) and an advanced adult (right). **(I=start** movement; 11= start one-sided support; **III=** Kick; IV = end of one-sided support).



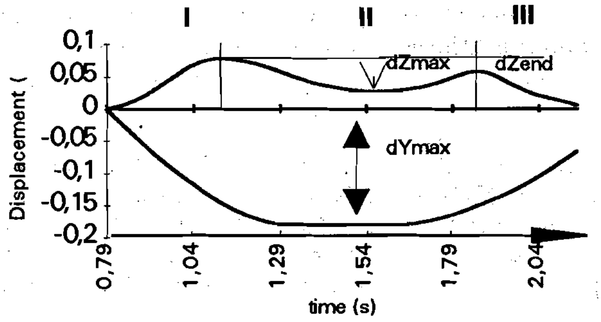


Fig. 3:Displacement of the kicking foot relative to the left foot from a beginning child (dotted lines) and an advanced adult (full lines).

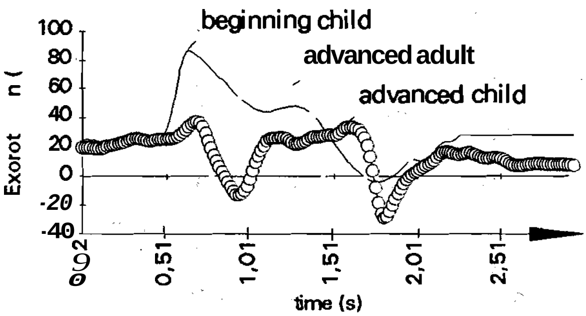
Fig. 4:Displacement of the total centre of gravity from a beginning child (I= enarming, 11= kicking, III= disarming).

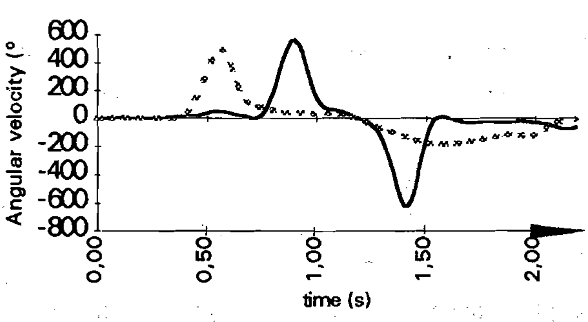
The 'Mawashi Gheri' is a relatively slow technique (the whole movement takes 1.7 to 2.2 seconds) and starts with a countermovement push off (from point I to II in fig.2) of 0.4 to 0.8 seconds (24 to 34 % of the whole movement). During this push off the force plate is fully unloaded for about 20 to 100 msec. From the displacement of the the right foot (fig.3), it was verified that the one-sided support starts at the instant the vertical reaction force reaches the G level (weight of subject; point II in fig.2) and ends at the end of a plateau in this force curve (point IV in fig.2). This is true for all subjects. The actual lash (point III in fig.2) is delivered after 0.98 to 1.32 seconds from the onset of the movement and is characterized by a downward-upward-downward curvation in the vertical force. This curvation is steep and more pronounced in advanced combatants.

Based on the vertical displacement of the body's centre of gravity (fig.4), the OSS can be subdivided in an enarming, kicking and disarming phase. Enarming raises the centre of gravity above the support and takes about 35 % of the OSS. The kicking phase takes about 30 to 46 % of the OSS in advanced performers, but beginners need 56 % of the OSS. The long duration of this phase in beginners is mainly due to a none active return of the leg after delivering the actual lash. Disarming takes another 1/3 of the OSS in trained subjects. Beginners spend much less time in this phase since they drop their leg immediatly down after kicking.

Along with the remarked disproportion of the kicking and disarming phases, a deviation in the sequence of rotational movement was seen in beginners. Fig.5 shows the time course of the orientation of the supporting foot in respect to the pelvis (called the exorotation of the supporting leg). An exorotation of zero degrees **meens** that the foot is perpendicular to the pelvis. The initial exorotation is about 20 degrees in all subjects. Beginners proceed by enlarging **this** angle (caused by a rather large outward rotation of the foot). The pelvis follows this rotation after a while (slowly decrease in the angle). Advanced performers start the movement with an inturning action of the pelvis (diminishing the exorotation angle toward a slight endorotation), followed by a quick outward-inward twist of the supporting foot during the kicking phase. The inward rotation is faster and slightly bigger then the outward. This accentuation of the inward rotation of the supporting foot is not seen in beginners; the speed of the **inturning** movement is practical zero (fig.6 and table 1).

Synchronizing the graphs of pelvic rotation with the acceleration curves, it can be seen that the minimum vertical acceleration **occours** at the instant the pelvis initiates the returning movement. This negative acceleration is (averaged) -7.34 **m/s²** in advanced and only -4.23 m/s² in beginners. It is presumed that this minimum acceleration can serve as an indicator wether or not the returning movement was active.





Fig; 5 : **Exorotation** in the supporting leg in a beginning and an advanced child, and in an advanced adult

Fig. 6 : Angular velocity of the out and inward rotation of the supporting foot in a beginning child (dotted lines) and an advanced adult (full lines)

Parameter	BK1	BK2	AK1	AK2	AA1	AA2	AA3
Age	12	12	12	15	21	25	35
Level	7° Kyu	7° Kyu	3° Kyu	3° Kyu	1° Kyu	1° Kyu	1°Dan
Duration of Push off (s)	0.737	0.435	0.744	0.504	0.833	0.492	0.708
- one-sided support(s)	1.44	1.36	1.43	1.2	1.1	1.52	1.21
- of whole movement(s)	2.177	1.802	2.172	1.704	1.928	2.016	1.92
- of the lash (kick) (s)	0.170	0.103	0.168	0.077	0.077	0.090	0.077
- of enarming phase (% of OSS)	24.6	40.3	24.6	34.5	35.4	46.7	36.0
- of disarming phase(% of OSS)	19.6	none	29.4	36	30.9	24.4	42.5
- of kicking phase(% of OSS)	55.8	59.7	46	29.5	33.7	36	46.7
Min vertical acc. CG(m/s²)	4.82	-3.65	-7.59	-9.20	-6.55	-8.22	-5.14
Max vertical acc. CG (m/s²)	2.25	3.75	5.22	8.00	2.93	4.91	4.80
Min vertical velocity CG (m/s)	-0.29	-0.49	-0.52	-0.80	-0.51	-0.80	-0.36
Max vertical velocity CG (m/s)	0.37	0.53	0.58	0.55	0.53	0.74	0.55
Max vert. downward displ CG(m) during kick	-0.048	-0.049	-0.037	-0.023	-0.034	0.042	0.014
Vert downward disp. CG (m) after kicking	-0.020	-0.092	-0.099	-0.009	-0.024	+0.042	-0.07
Hor.position CG (m) rel. to left foot at begin	-0.23	-0.43	-0.28	-0.23	-0.42	-0.48	-0.30
Max horiz. disp. CG in OSS (m)	0.18	0.26	0.21	0.16	0.22	0.31	0.23
Total horiz. disp.CG (m) in movement	0.30	0.42	0.37	0.26	0.32	0.45	0.30
Max angular displ. (°) supporting foot	90	75	97	-	90	116	101
Max angular displ.pelvis (°)	83	33	96	67	44	104	48
Max angular disp.shoulder	34	78	62	36	35	58	36
Max exorotation (°) supporting leg	72	75	26	-	66	44	71
Max angular velocity ("Is) supporting foot	474	189	334	400	444	425	555
Min angular velocity ("Is) supporting foot	-158	-94.5	-584	-	-688	-800	-621
Max angular vel. (°/s)	200	136	286	207	112	162	207
Min angular vel.pelvis(°/s)	-176	-64	-220	-180	-128	-137	-72
Width of standing base (m)	0.65	0.83	0.61	0.67	0.87	0.87	0.64
Proportion (%) standing base / length legs	87	106	82	89	105	105	76
% body mass on left (%) foot at begin	48	47	46	58	49	46	40
Orientation standing base (°) rel to sag plane	36	5	25	22	17	23	22
Max vertical velocity (m/s) kicking foot	4.9	4.4	3.4	4.8	5.6	7.2	8.2
Max horizontal velocity(m/s) kicking foot	5.1	4.5	3.9	4.7	4.7	5.3	7.6
M i vertical velocity (m/s) kicking foot	-2.4	-4.4	-3.6	-3.3	-5	-2.2	-4.3
M i horizontal velocity(m/s) kicking foot	-1.9	-4.2	-2.5	-3.8	-4.2	-4.9	-3.6
Height of kick (%) (relative to length Subject)	82	85	82	85	85	93	87

Table 1: Summary of descriptive parameters derived from the **Mawashi** Gheri performed by 7 subjects.

CONCLUSSION

Two major differences were noticed comparing poor and good performances of the '**Mawashi** Gheri' :

1- Beginners **performe** a rotation with the supporting foot prior to the hip rotation **wich** is he opposite of the motion sequence seen in experts. In addition, adults rotate the foot more and the hip less then children.

2 - Beginners do not perform an active return after the **kick** and end in a passive way. This prolonges the **kicking** phase and disables the subject to start immediatly a new **kick** without going through the disarming phase and a new **enarming** phase.

The active return of the leg is clearly visible in the vertical acceleration curve.

It is advised to not stress a deep standing base at the beginning of the learning process of the '**Mawashi** Gheri', since this enforces a push off with the hind leg, hinders the expected first action of the hip and contributes to a disproportional movement sequence.

REFERENCES :

Berme and **Cappozo,** 1990, Biomechanics of Human Movement, **Worthington,** Ohio.
Hanavan , 1964, Technical report **AMRL-64-102,** Ohio.
Plagenhoef, Patterns of human motion, a cinematographic analysis, New Jersey.
Usui **,** 1982, IEEE, **vol.** BME-29, no 10.