SIMULATION OF BALL HANDLING IN OVERHEAD PASSING IN VOLLEYBALL

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The purpose of this study was to obtain basic data to be used for teaching ball handling in overhead passing in volleyball. The method used was simulation of a mass-elasticity-viscosity model consisting of arms, hands and ball. First, the acceleration of the ball was calculated during contact with the hands through means of VTR images. As a result of comparing this acceleration with that of the simulation of the model, it was found to be appropriate, and the coefficients of elasticity and viscosity were sufficient. The coefficients indicated that a skilled player changes hand elasticity depending on the height of set up. This is the reason that skilled players can control the ball with a greater degree of accuracy. On the other hand, unskilled players can not change hand elasticity as easily, which affects their control of the ball.

KEY WORDS: volleyball, overhead passing, mass-elasticity-viscosity model, simulation, video motion analysis

INTRODUCTION: Overhead passing is by far the most the preferred skill that is used when setting the ball. It can be used for other purposes as well, including passing a down or free ball, covering tips, and performing an attack volley. Overhead passing provides more accurate ball control than forearm passing, but is no defense against a hard-driven ball. The ball is hit without delay in most techniques. However, in overhead passing, the ball is actually caught, then thrown. Because this is a momentary action, it is not considered a fault. In addition, the ball bounces with its own elasticity in most techniques. However, in overhead passing, the ball's elasticity is first absorbed by the hands then accelerated in its release by the player's force, as opposed to bouncing as a result of its own elasticity.
For the purpose of obtaining basic data for teaching ball handling in overhead passing in volleyball, an attempt was made to simulate a collision between a ball and a player's upper extremity by use of a mass-elasticity-viscosity model.

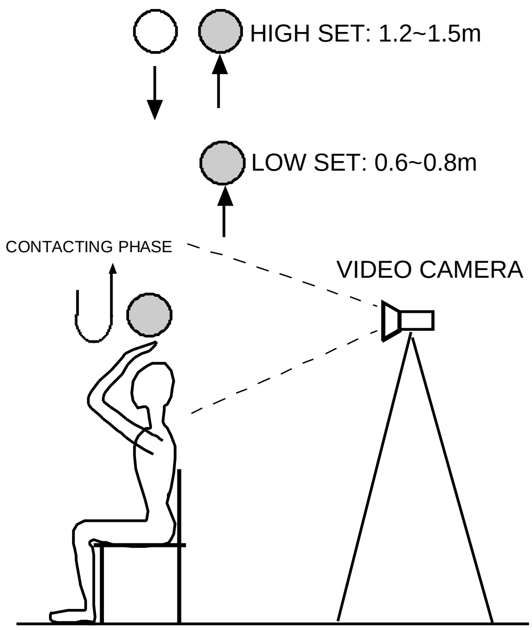

Figure 1 - Condition of experiment.

METHODS: Condition of Experiment. Figure 1 shows the condition of the experiment. To insure identical trial conditions, the ball was dropped from the right side over the passing position of the subject. To restrict the subject to use of only arms, the subject sat on a chair. The motion of overhead passing executed under this condition was recorded by a high-speed video camera (RGB-Rabbit: PHOTORON). The shutter speed was 1000ms and the frame rate was 250fps. The ball used in this experiment was an official ball approved by FIVB, with a weight of 0.273kg, 0.655m in diameter and with 0.31hp/cm^3 inside pressure.
Description of Trials. Two types of trials were conducted. The first consisted of passing a ball which was dropped from a height of 1.2m up to 1.2~1.5m, defined as "HIGH SET". A second trial involved passing a ball dropped from a height of 1.2m to 0.6~0.8m, defined as "LOW SET". These trials were visualized as a setting by the setter for the tandem offence.
Subject. For the skilled male subject, a setter

on the Oita University Men's Volleyball Team was selected. For the intermediate-level female subject, a setter on the Oita University Women's Volleyball Team was also selected. For the unskilled male and female subjects, students who have experienced playing volleyball only in school classes were selected.

Motion Analysis. Images taken by high-speed VTR were captured by personal computer through IEEE 1394 interface. Digitization of the ball trajectory was performed, by clicking the mouse manually, on the screen of a personal computer. Limiting the range to contacting phase, the vertical velocity and the vertical acceleration of the ball were calculated by differentiating the vertical component of the positional coordinate of the ball.

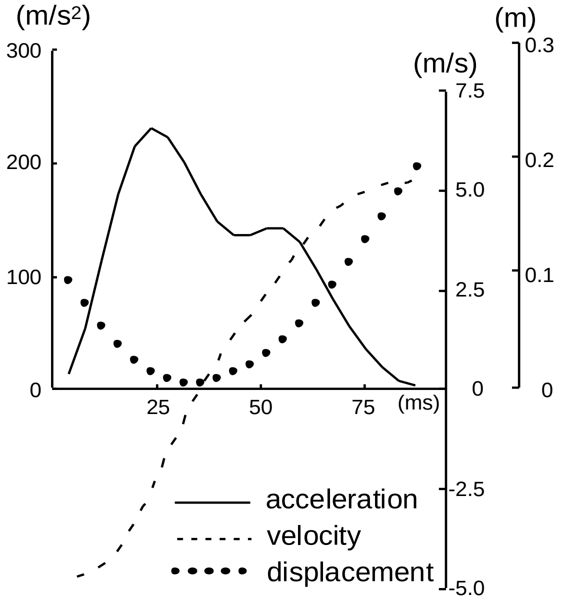

Figure 2 - Displacement, velocity, acceleration of the ball during contact calculated from video images.

Due to motion analysis from VTR images, the data contained a lot of noise, including digitizing error. First, positional data of the ball was smoothed by use of least-square smoothing formula, then differentiated twice. Furthermore, high frequency noise was cut by use of the filter applied FFT. Figure 2 shows that velocity and acceleration differentiated from displacement during ball contact.

The Mass-Elasticity-Viscosity Model of Overhead Passing. The collision between ball and the body's upper extremity was expressed as a series mass-elasticity-viscosity model shown in Figure 3. Considering the function of upper extremities in overhead passing, there seem to be two components. One is the component that directly absorbs the ball's momentum and controls the ball's direction, while another is that which accelerates the ball. M_1 is mass of ball. M_2 is whole mass of upper extremity. K_1 and K_2 are elasticity components of function of upper extremity. C_1 and C_2 are viscosity components of function of upper extremity. The equations of motion concerning the mass-elasticity-viscosity model of overhead passing are as follows:

$$m_1 \frac{d^2x_1}{dt^2} = -k_1(x_1 - x_2) - c_1\left(\frac{dx_1}{dt} - \frac{dx_2}{dt}\right) - m_1 g \qquad (1)$$

$$m_2 \frac{d^2x_2}{dt^2} = -k_2 x_2 - c_2 x_2 - m_2 g - m_1\left(\frac{d^2x_1}{dt^2} + g\right) \qquad (2)$$

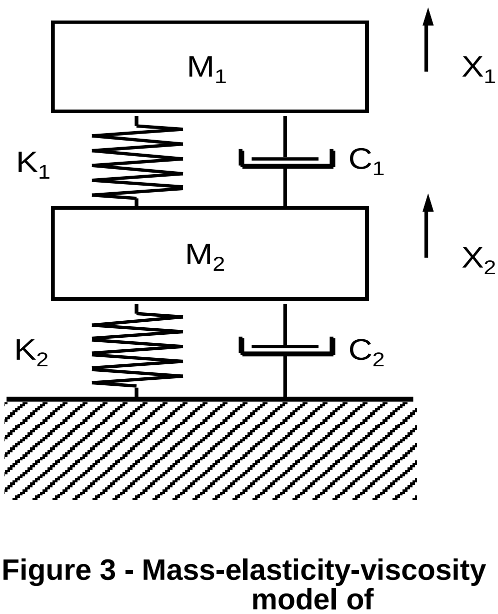

Figure 3 - Mass-elasticity-viscosity model of

Simulation. Starting with the initial values, displacement x_1[0], x_2[0], velocity v_1[0], v_2[0], and numerical solution for differential equations were obtained by using numeric analysis function of software (Mathematica: Wolfram Research). v_1[0] as initial speed of the ball (M_1) was –4.85m/s, and v_1[0] as initial speed of upper extremity (M_2) was 0m/s. m_1 was reduced

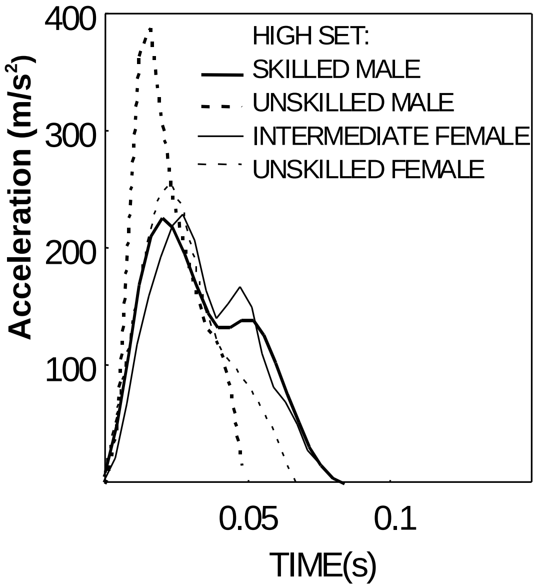

Figure 4 - Vertical acceleration of the ball in HIGH SET calculated from motion analysis.

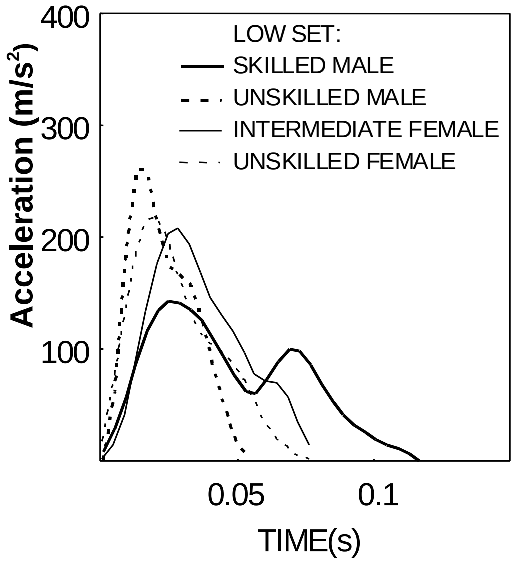

Figure 5 - Vertical acceleration of the ball in LOW SET calculated from motion analysis.

mass of ball. m_2 was calculated as the reduced mass of upper extremity by use of the mass ratio of Matsui's human body mass index (Matsui, 1958). k_1, k_2, c_1, c_2, $x_1[0]$, $x_2[0]$ which was altered to set the difference at a minimum between the motion analysis curve and the simulation curve c_1 was ignored in all subjects, because it was small. In this study, it is interpreted to mean that there is not enough viscosity to affect the ball.

RESULTS AND DISCUSSION: Acceleration of the Ball from Motion Analysis. The accelerations calculated from VTR images are shown in Figure 4 and Figure 5. Figure 4 shows HIGH SET by all subjects, Figure 5 shows LOW SET by all subjects.

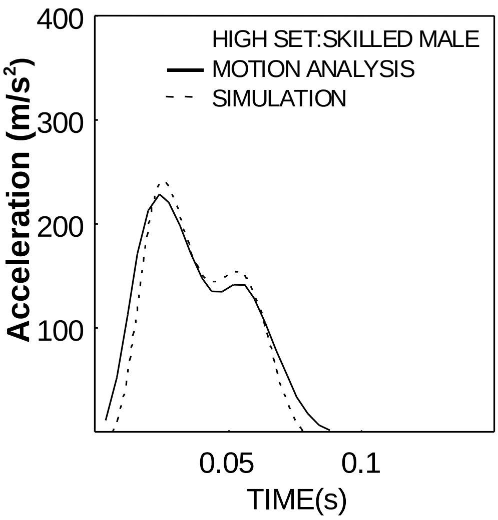

Figure 6 - Vertical acceleration of the ball calculated from Simulation and motion.

Concerning HIGH SET, the peak of the unskilled male was higher than the other subjects, which indicates hard impact. The unskilled female's curve, like that of the unskilled male, became smaller. The skilled male's and intermediate female's curves, were similar with two peaks.

Concerning LOW SET, only the skilled male's curve had two peaks. The starting phase of the curve of unskilled male/female was steeper than that of the other two subjects.

From these figures, it can be said that the less skilled the subject, the shorter are the contacting time and the higher the peak of acceleration. Because unskilled subjects have no experience in volleyball, they show a tendency to hit the ball without absorbing its momentum.

When data on both male subjects were analyzed, the peak of acceleration was higher and contacting time was shorter in HIGH SET. In the case of both female subjects, there was

Table 1 Coefficients and Initial Values Obtained by Simulation

	MALE				FEMALE			
	SKILLED		UNSKILLED		INTERMEDIATE		UNSKILLED	
	HIGH	LOW	HIGH	LOW	HIGH	LOW	HIGH	LOW
c_2	250	200	100	160	10	100	150	50
k_1	10000	500	60000	10000	3500	1500	5000	2000
k_2	160000	100000	280000	280000	150000	90000	120000	110000
$x_1[0]$	-0.058	-0.28	-0.034	-0.12	-0.15	-0.21	-0.13	-0.21
$x_2[0]$	-0.04	-0.08	-0.014	-0.021	-0.026	-0.038	-0.03	-0.023

no appreciable difference between HIGH and LOW as regards the peak of acceleration and the contacting time. This might be because that muscle strength of females is not as developed as their male counterparts.

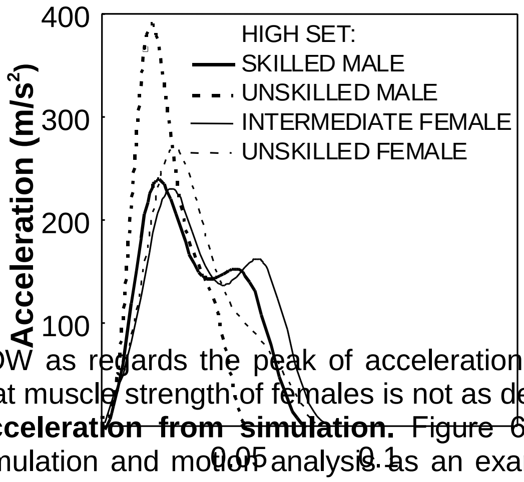

Figure 7 - Vertical acceleration of the ball in HIGH SET calculated from simulation.

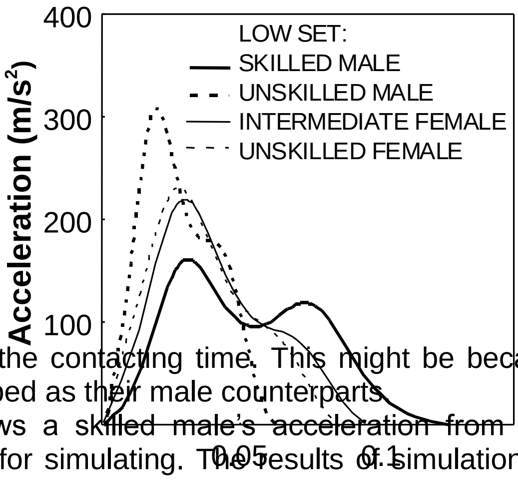

Figure 8 - Vertical acceleration of the ball in LOW SET calculated from simulation.

Acceleration from simulation. Figure 6 shows a skilled male's acceleration from both simulation and motion analysis as an example for simulating. The results of simulation are shown in Figure7 and Figure 8. Figure 7 shows HIGH SET of all subjects, and Figure 8 shows LOW SET. Table 1 shows coefficients and initial values obtained by simulation. A curve similar to the real curve from motion analysis was simulated by solving differential equations with altering values of k_1, k_2, c_1, c_2, $x_1[0]$, $x_2[0]$.

All subjects caused K_1 to react like a soft spring, and K_2 to react like a stiff spring.

Comparing the two trials of the skilled male subject, all coefficients in LOW SET were smaller, especially k_1, while $x_1[0]$ and $x_2[0]$ were larger minus figures. This shows that when the subject sets lower, the subject reduces the force to the ball by softening K_1.

As for the unskilled male subject, k_1 and k_2 of both trials were largest in all subjects. This demonstrates that the subject strained too much in HIGH SET and could not weaken K_1 enough to reduce force in LOW SET. This is because the subject has had no experience handling a volleyball.

Comparing trials of the intermediate female subject, k_1 and k_2 were smaller, while c_2, $x_1[0]$ and $x_2[0]$ were larger in LOW SET. The change in k_2 from HIGH SET to LOW SET was similar to the skilled male subject. On the contrary, the subject could not make K_1 stiffer unlike the

skilled male in HIGH SET. Instead of making K_1 stiffer, the subject might produce force by enlarging $x_1[0]$.
The unskilled female subject also could not make K_1 unlike the male in HIGH SET. Instead of making K_1 stiffer, the subject probably produced force by enlarging $x_1[0]$. k_1 of both HIGH and LOW were larger than the intermediate female's. This causes her to have less control over the ball. Throughout the simulation, it can be concluded that K_1 is the function of hands, while K_2 and C_2 are the functions of arms.

CONCLUSION: An attempt was made to simulate a collision between a ball and a player's upper extremity in overhead passing by use of the mass-elasticity-viscosity model.
The results are as follows:
(1) It was found that the model of overhead passing in volleyball in this experiment was appropriate. In addition, it was found that K_1 is the function of hands, and K_2 and C_2 are the functions of the arms.
(2) The coefficients in this experiment showed that a skilled player changes hand elasticity, depending on the height of set up. This is the reason skilled players can control the ball more accurately. On the other hand, an unskilled player can not change hand elasticity as easily, which is why unskilled players can not control the ball with the same degree of proficiency as experienced players.

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