Experimental study on drowning accident risk in river and side ditch

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Climate change increases the frequency of torrential rains and drowning accident frequently occurs. Therefore, it is very important to study the hydrodynamic force exerted on the human body in flood water. In this study, two kinds of the flume experiments were conducted using a small-scale model of the human body. First, we measured the drag force exerted on the human body in flood water. Second, we examined the drowning accident risk in a narrow side ditch. Flume experiments were conducted by changing the flume width (In real scale, B=1.6m, 0.8m, 0.4m). Drag force exerted on the human body model was measured by a Force gauge. The results can be used as primary assessment to define the drowning risk in a river or a channel after torrential rain.

Fig.1 shows the drag force measurement set-up. Hydrodynamic force on the human body model (1/10 scale) in x-direction was measured by a force gauge. Sampling rate is 10Hz and sampling time is 60s.

Considering falling down in the flood water, the posture of the human body was changed (standing and sitting). Human body model heights are k_1=15cm (real scale: 1.5m, 12 year child) for standing position and k_2=7cm (real scale: 0.7m) for sitting position. To investigate the effect of clothing, we put cotton clothes on the human body model. Bulk mean velocity U_m and water depth H were changed (In real scale, flow depth H=0.35, 0.50, 0.70m and flow velocity U_m= 1.0, 1.5, 2.0m/s). When H=0.7m, the leg was submerged for standing position and the whole body was submerged for sitting position. Table 1 shows the hydraulic condition.

Second, flume experiments were conducted by changing the flume width (In real scale, B=1.6m, 0.8m, 0.4m), as shown in Fig.2. Drag force exerted on the human body model (1/4 scale) was measured by a force gauge. Human body model heights are k_1=30cm (real scale: 1.2m, 8 year child) for standing position and k_2=21cm (real scale: 0.84m) for sitting position.

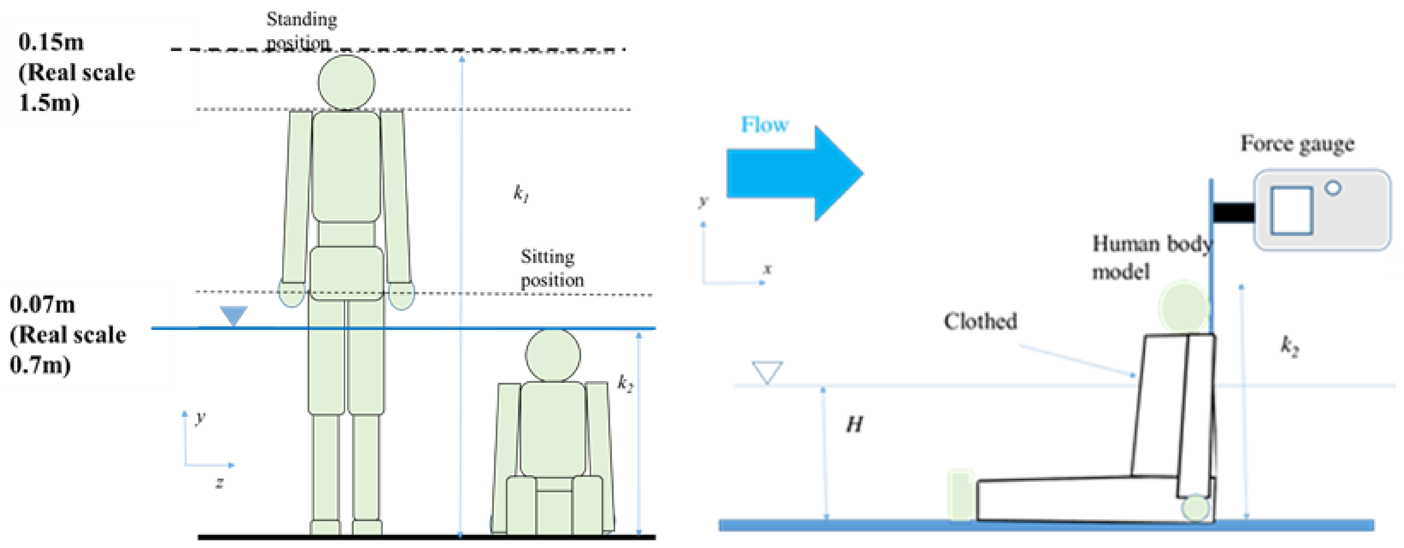

Fig.1(a) Posture change of human body model (1/10 scale), (b) Drag force measurement

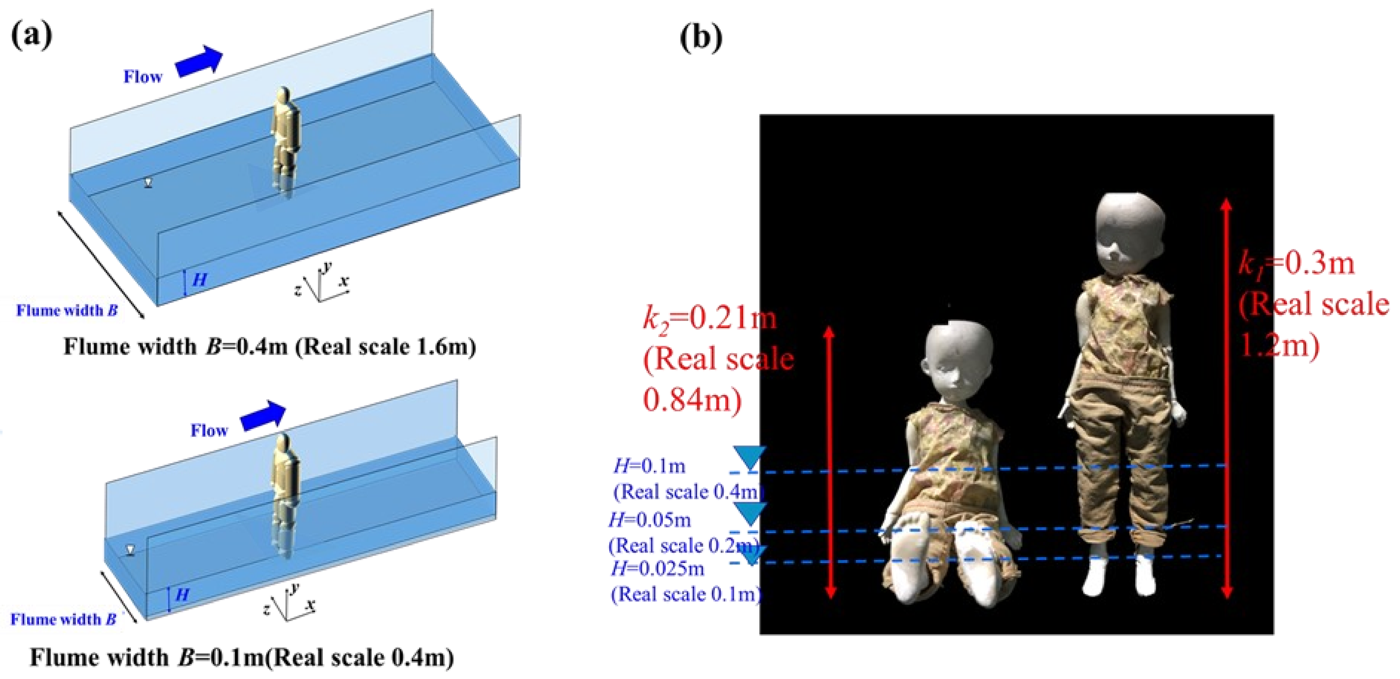

Fig.2(a) Change of flume width, (b) Posture change of human body model (1/4 scale)

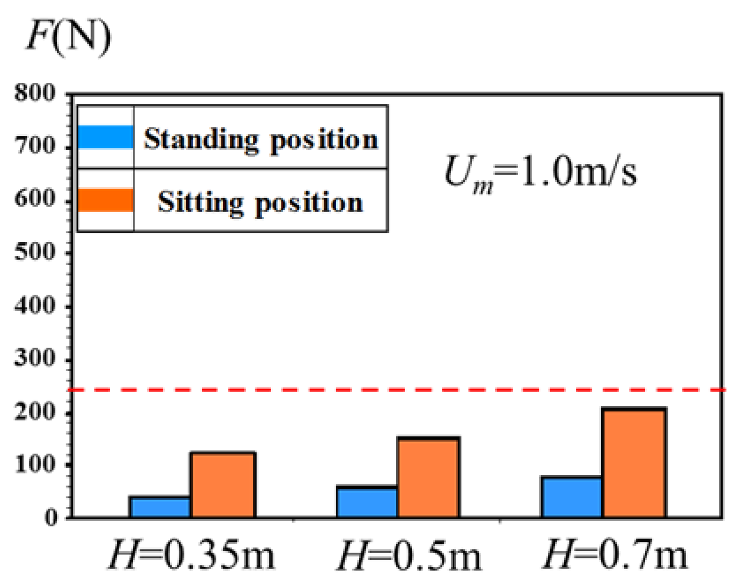

Fig.3 Drag force exerted on human body (effect of posture change)

Fig.3 compares the values of the drag force exerted on the human body (1/10 scale) in a standing position and in a sitting position (unclothed case). The drag force values were converted to the force values in real scale. The experiment data showed that the drag force in a sitting position is 2-3 times larger than that in a standing position. This is because the projected area normal to the incoming flow increases in a sitting position, considering the falling down in flood water.

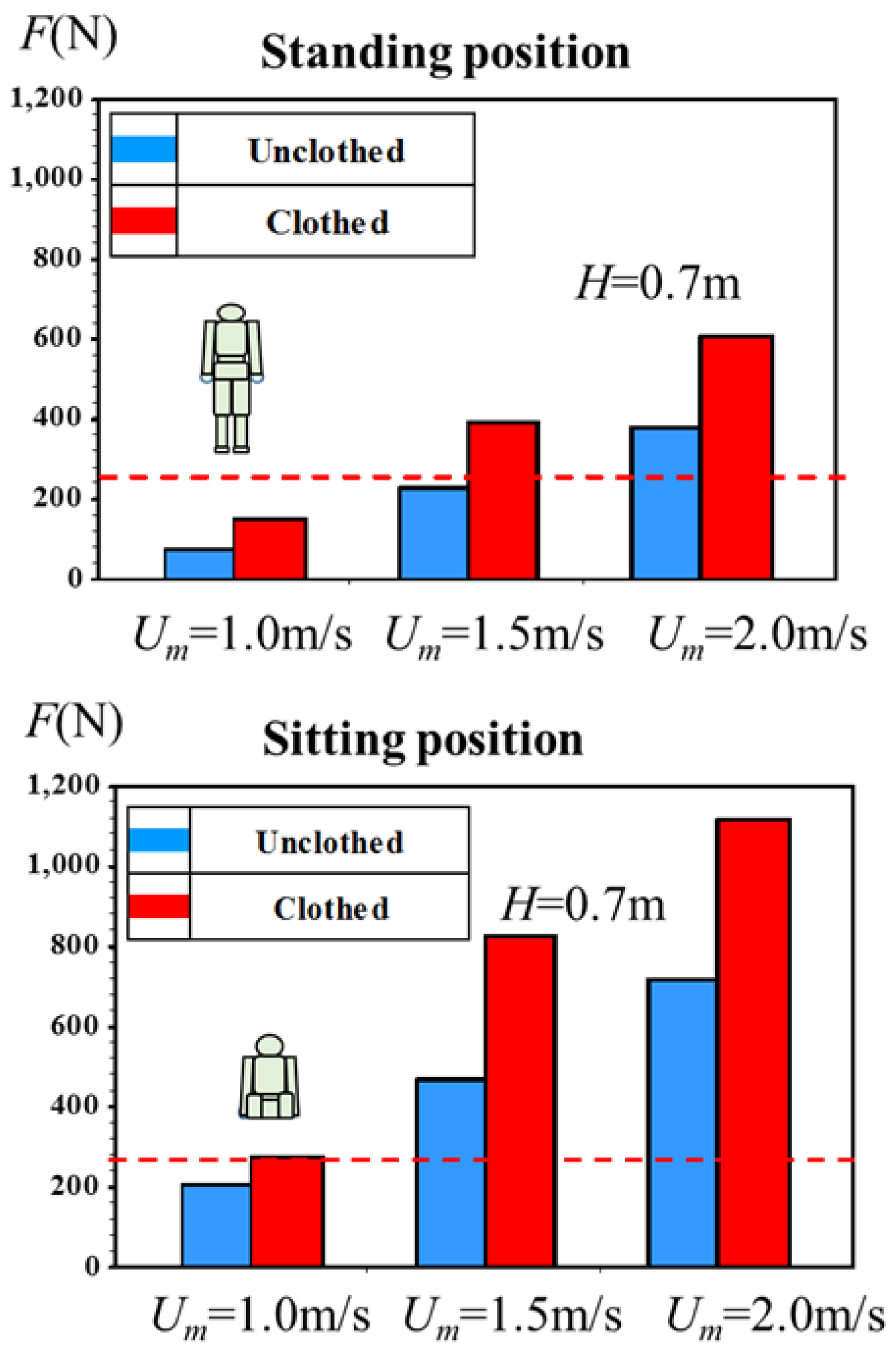

Fig.4 Drag force exerted on human body (effect of clothing)

Fig.4 compares the values of the drag force exerted on the human body (1/10 scale) for unclothed and clothed cases. The flow depth is H=0.7m in real scale. In a standing position, the drag force exerted on the human body increases by 57% for clothed case compared with that for unclothed case.

$$F_D = 0.5\rho C_D U_c^2 A_x = S = \mu(Mg - F_b)$$

$$F_b = \rho g Vo$$

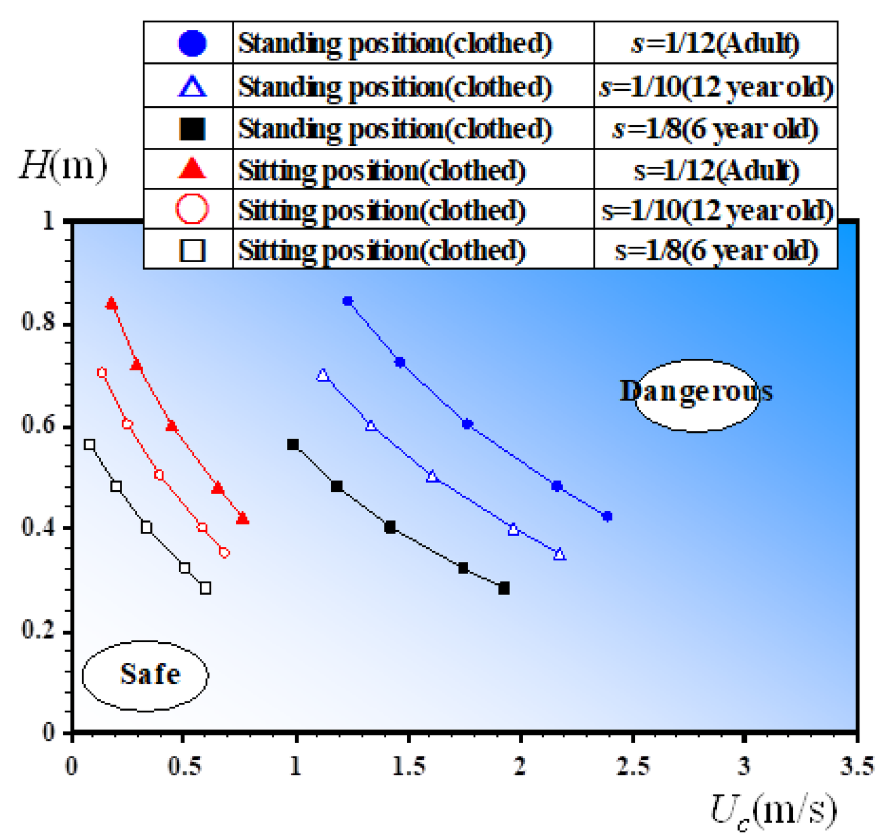

Fig.5 Critical condition for drowning accident (6 year old, 12 year old, adult)

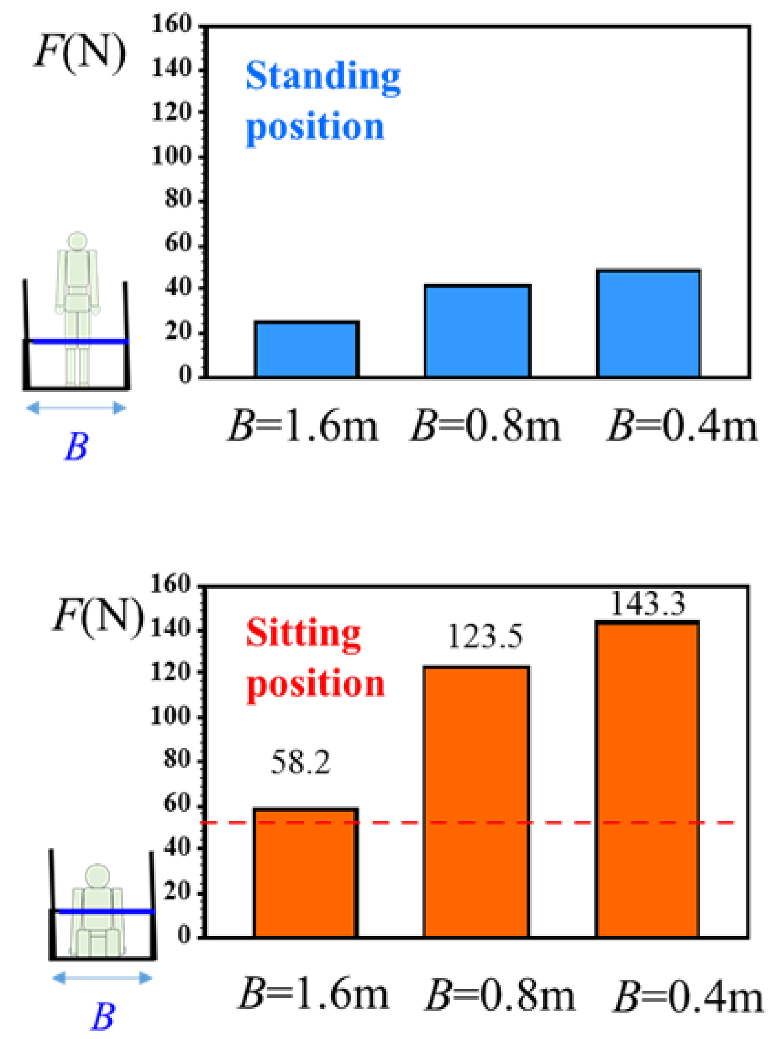

Fig.6 Drag force exerted on human body (effect of flume width)

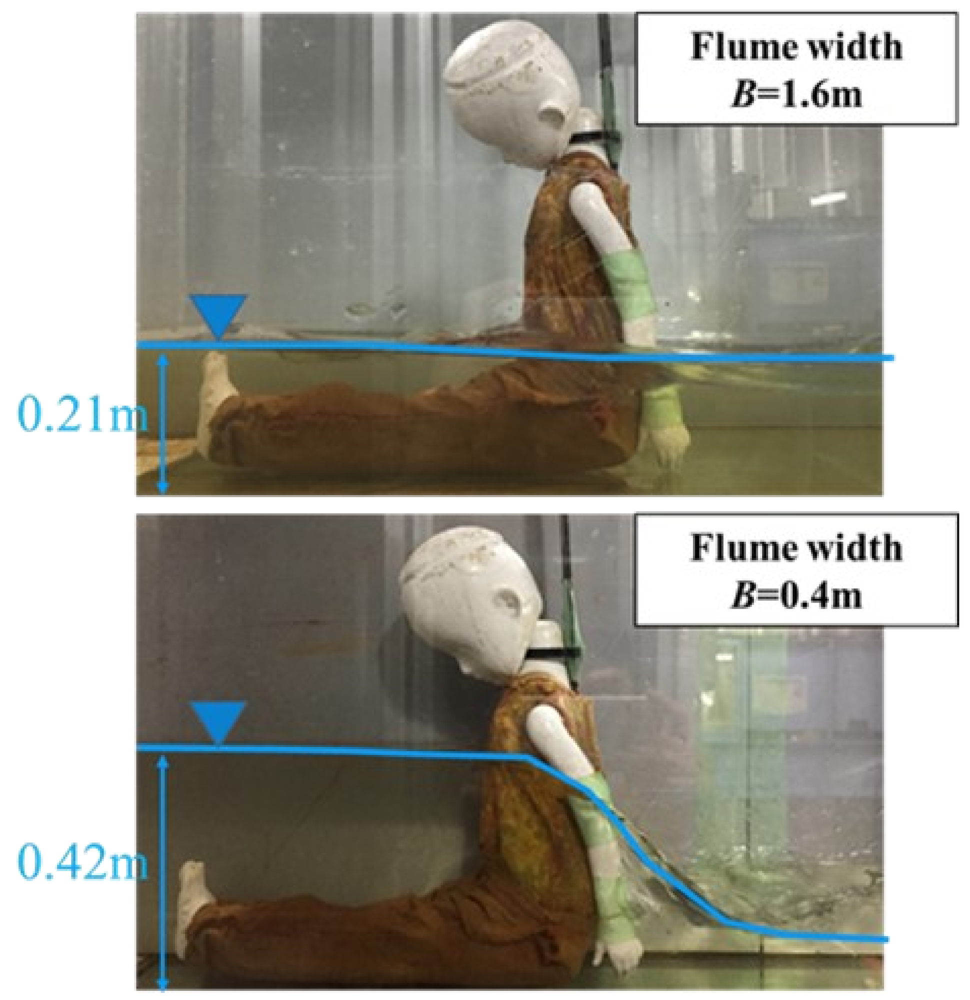

Fig.7 Backwater rise in narrow side dicth

Fig.5 shows the critical velocity U_c of 12-year child (M=46kg) for drowning accident in a wide channel. The critical velocity U_c for 8 year child (M=46kg) was also calculated using scale ratios.

For the same water depth, the incipient velocity in a sitting position is smaller than that in a standing position. There are two reasons. First, the drag force exerted on the human body increases in a sitting position compared with that in a standing position. Second, the submerged volume of human body becomes larger in a sitting position and consequently, the frictional resistance S decreases.

Fig.6 compares the values of the drag force exerted on the human body (1/4 scale) in a wide channel and a narrow channel. The experiment data showed that the drag force in the narrow channel is 2 times larger than that in the wide channel.

For a narrow channel, the backwater rises in front of the human body (Fig. 7) and the hydrostatic pressure is exerted on the body. The buoyancy force acting on the body increases due to the backwater rise.