# MEASUREMENT OF FORCES EXERTED DURING SWEEPING IN CURLING

**Hitoshi Yanagi, Katsumi Miyakoshi, Yasushi Nakajima, Noriyuki Yamamoto*, and Tadao Isaka****

**Kitami Institute of Technology, Kitami, Japan; * Japanese Red Cross Hokkaido College of Nursing, Kitami, Japan; ** Ritsumeikan University, Kusatsu, Japan**

**KEY WORDS:** curling, sweeping, force measurement

**INTRODUCTION:** Sweeping is performed to correct the speed or the trajectory of the stone thrown in the game of curling. Curlers are asked to sweep the ice in front of the sliding stone strongly. Therefore we attempted to develop a simple device for measuring the forces exerted on the brush during the sweeping. The present study compared the forces exerted on the brush with the ground reaction forces during the sweeping.

**METHODS:** Six subjects with the different curling experience volunteered to participate in the laboratory test. They were instructed to sweep the force plates covered with a polypropylene sheet with maximum efforts for 5 sec three times. A commercially available curling brush was used to develop the device in the study. It consists of a head and a shaft with a ball-and-socket joint combined to it. Eight strain gauges were attached to the shaft 150 mm far from the joint center to detect the loads in the direction of the shaft axis and the direction perpendicular to it. The potentiometer was attached to the shaft to detect the angle between the shaft and the ice surface. The amplified signals from the strain gauges were digitized and sampled by the A/D converter. The forces on the brush were calculated as the forces applied to the ice surface vertically ($F_{V\ brush}$) and horizontally ($F_{H\ brush}$) based on the output from the strain gauges and the shaft angle. The vertical ($F_{V\ fp}$) and the horizontal ground reaction forces ($F_{H\ fp}$) on the force plates were also recorded during the sweeping. Force data were averaged over 5-sec period for each trial. The force exerted on the brush and the ground reaction force were expressed as the mean and *SD*. Two-way ANOVA was used to determine significant differences between these data and between subjects. Correlation coefficient was used to examine the relationship between the force exerted on the brush and the ground reaction force during the sweeping for each trial.

**RESULTS AND DISCUSSION:** The 5-sec averaged force data and the correlation coefficients were shown in Table 1. There were significant correlations and no difference between $F_{V\ brush}$ and $F_{V\ fp}$. However, $F_{H\ brush}$ was significantly lower than $F_{H\ fp}$ ($p$<0.01). This would be due to the fluctuation of the joint center height, which was a factor used for calculating the shaft angle, during the sweeping. Significant differences between subjects were found in the vertical force data ($p$<0.01). It was thought that the force data reflected the performance level of the curlers.

**Table 1 Mean and *SD* of the force data and correlation coefficients between the force exerted on the brush and ground reaction force. * indicates $p$<0.01.**

| | $F_{V\ brush}$ (N) | $F_{V\ fp}$ (N) | $F_{H\ brush}$ (N) | $F_{H\ fp}$ (N) |
|---|---|---|---|---|
| Mean (*SD*) | 195 (66) | 204(58) | -17(5) * | 7(5) |
| Correlation coefficients | 0.970-0.995 * | | 0.824-0.957 * | |

**CONCLUSION:** These results demonstrated that the simple device with the strain gauges and the potentiometer enables the force measurement during the sweeping in curling. A noncontact sensor for detecting the shaft angle would be necessary to improve the accuracy of the measurement and the usability of the device.