PRELIMINARY ASSESSMENT OF THE EFFECT OF TRAPEZE POSTURES ON RIGHTING FORCE IN SAILING

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This study examined the effect of change of “Trapeze” postures in sailing on the horizontal force for righting the boat. Three healthy university sailors participated. The subjects were instructed to successively change their trapeze posture. The traction force of the wire was measured from which its horizontal component for righting the boat (FH) was computed. A distinct change of FH was observed when the subjects extend their legs during trapezing. From this result, it can be suggested that the change of the trapeze posture by extending the leg linked to expand the angle between the wire and mast, thereby contributing to the increase the resultant FH.

KEY WORDS: dinghy, trapeze, traction force, harness

INTRODUCTION: Among many skills required in sailing, “Trapeze” handling as seen in many dinghy classes is one of the most unique and important one. The function of the trapeze is to enable the sailors to exert a righting force by getting their body further out of the deck. In particular, when a boat sails windward, this skill has an essential role to stabilize the boat in the frontal plane and thereby facilitating an efficient drive of the boat. As the wind is always changing, the sailors adjust the righting force by changing their posture.
Several studies (Mackie et. al., 1999a & 1999b; Pearson et. al., 2005) focused on other sailing skills like hiking and grinding. However, to date, there has been no biomechanical study that analyzed the trapeze skill. The purpose of this study, therefore, was to examine the effect of the change of the trapeze postures on the righting force of the boat.

METHODS:

Subject: Three healthy sailors from university sailing team participated in this study. All subjects were well-experienced concerned the trapeze postures.
Experiment apparatus: As shown in Figure 1, an experimental apparatus which simulated the actual sailing condition was made in the laboratory. The length of the wire and the footing position was set equal to the actual dingy class boat. The load cell was installed between the wire and the harness to measure force at the wire. The sagittal plane motion of each subject during trapezing was recorded by a video camera at 30 fps.
Experiment procedure: Markers were attached to the subjects as well as the wire to analyze body and wire movement. When trapezing, the subjects were instructed to successively change their posture from posture 1 to 2, posture 2 to 3 and posture 3 to 4 (Figure2). In posture 4, subjects operated the adjuster and pull adjuster sheet for 10cm.
The way to data collection: The force data (F) was amplified by a strain amplifier (6M46, San-ei Instrument Co., LTD, Japan) connected to a computer (VAIO PCG-GRX90/P, SONY, Japan) to obtain the time series displacements.
The digitized points are shown in Figure 2 (posture 3); 9 points (head, shoulder, elbow, wrist, hip, knee, ankle, wire1, wire2) were manually digitized by a motion analysis system (Frame-DIAS for Windows, DKH, Japan) and their two-dimensional coordinates were calculated using two-dimensional direct linear transformation method (2D-DLT). The angle between the wire and mast was calculated. From the force (F) and the angle (θ), its horizontal component which is available for righting the boat (FH) was computed.
The change of the trapeze posture was defined by the horizontal distance of the center of mass of the body (DCM).

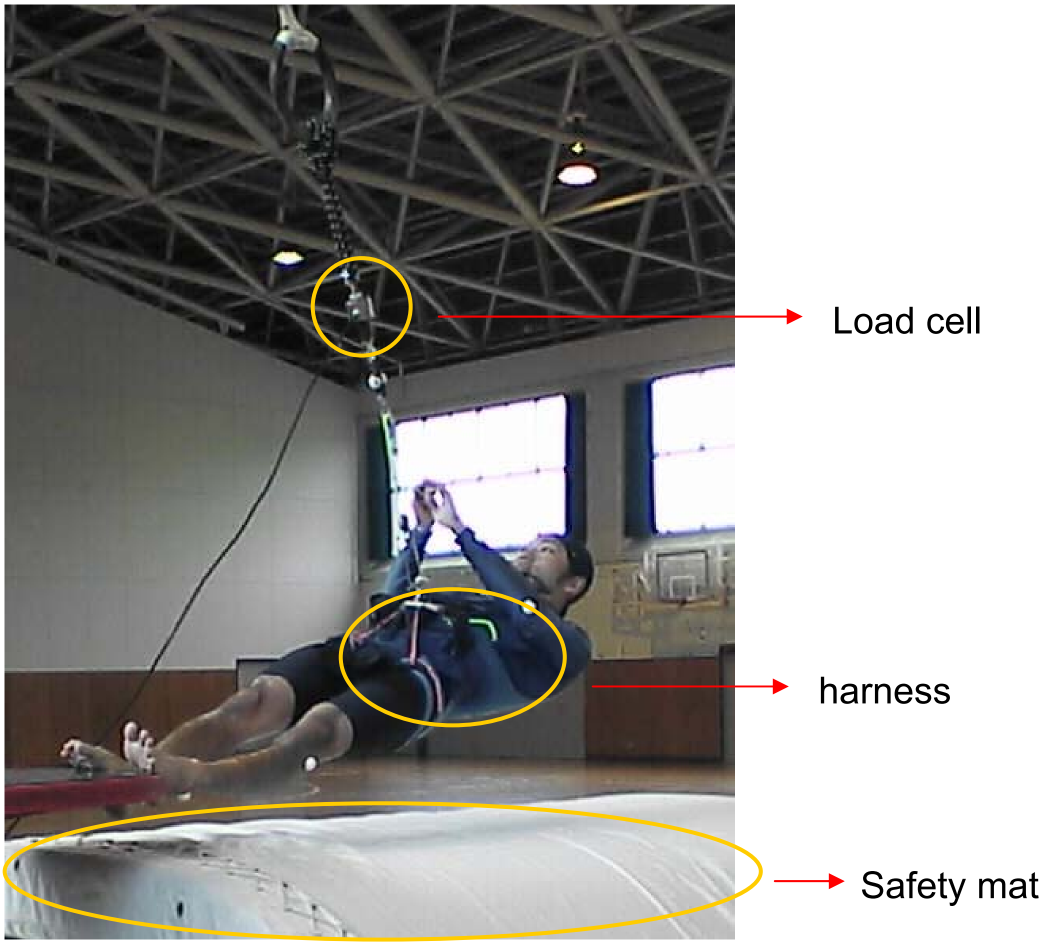

Figure 1. Experimental apparatus

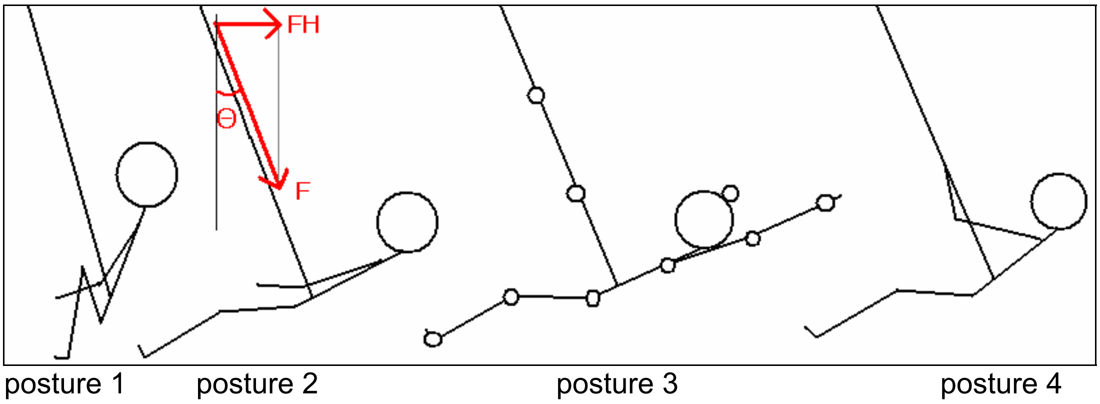

Figure 2. Definition of trapeze postures.

RESULTS AND DISCUSSION: Figure 3 shows a typical example of the time series data of FH. Figure 4 shows the correlation between FH and DCM for three subjects.
As shown in Figure 3, the magnitude of FH fluctuated distinctively when the subjects manipulated the adjuster. This action might cause the instability of the boat.
When the trapeze posture was changed from posture 1 to 2, the magnitude of FH was appreciably changed (Figure 3) and also a high correlation was observed in all subjects between FH and DCM (Figure 4). From these results, it can be seen that extending the leg links directly to the increase of the magnitude of FH whereas the traction force on the wire (F) is constant. It should be considered that the leg extending motion observed in the change of the trapeze posture (1 to 2) increased the angle (θ), thereby contributing to increase the horizontal force (FH) for righting the boat.

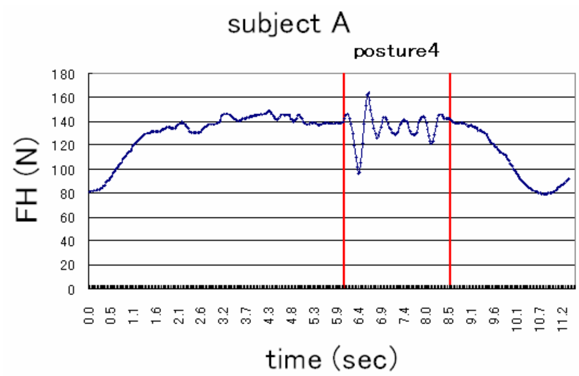

Figure 3. Typical example of FH throughout a series of change in trapeze posture.

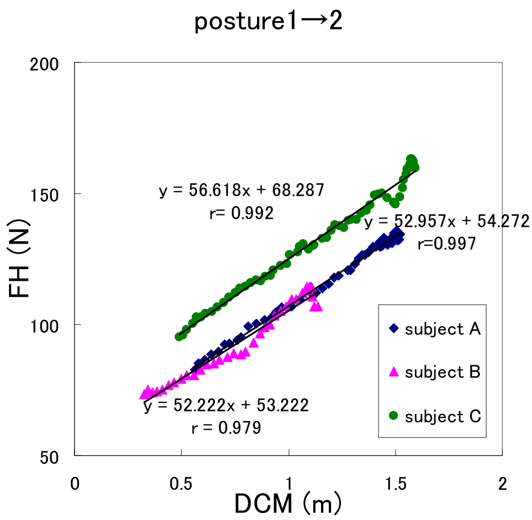

Figure 4. Correlations between the horizontal distance of the center of mass and traction force when trapeze posture was changed from 1 to 2.

Table1. Correlation coefficient in each change of posture

	F			FH		
	A	B	C	A	B	C
posture	r	r	r	r	r	r
1→2	0.882*	0.449*	0.026	0.997*	0.979*	0.992*
2→3	0.771*	0.886*	0.149	0.898*	0.944*	0.668*
3→2	0.133	0.047	-0.137	0.386*	0.267	0.492*
2→1	0.185	0.819*	-0.482	0.996*	0.995*	0.994*

* : $p < 0.05$

CONCLUSION:

- When trapezing, traction force on the wire (F) was 84.1%～108.3% of the body weight, and its horizontal component (FH) can be used for righting the boat, corresponding between 11.5% and 27.3% to the body weight (except for posture 4).
- The leg extension motion has a significant effect on the magnitude of FH.
- Sailors should manipulate the adjuster sheet with caution because FH can show large fluctuations during this action.

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