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Seat optimization for single handed Paralympic sailing boat

Stein Callenfels, van, KL[a,*], Ent, van der, M.[a], Berger M.A.M.[a]

** [a] The Hague University of applied sciences*
Human Kinetic Technology
Johanna Westerdijkplein 75
2521 EN The Hague, Netherlands

Abstract

PURPOSE: The aim of this study was to optimize the seat for the skipper of a 2.4mR, a Paralympic sailing boat (single-hander). Primarily, the seat was designed for a man with diastrophic dysplasia, a disorder of cartilage and bone development. This 39 year old man has a short stature with very short arms and legs and joint deformities which restrict movement. The skipper's main tasks are handling the rudder and the mainsheet using small ropes with his hands and pedals with his feet. He is sitting on a seat attached to the floor of the boat, while his body is positioned facing the bow of the boat. The combination of movements of the boat and tasks during sailing resulted in a constantly changing instability of the body. This might declare some of the injuries (pain in hips, knees and shoulders) that were called. The design goal for the seat was to find an optimum in body stability and range of motion during sailing.
METHODS: An analysis of the possible movements in the frontal and sagittal plane of the skipper in the boat was made using a mock-up. A movement analysis of sailing was made in three boat conditions: 1. Boat heeling 32° (sailing close hauled), bodyweight as much windward as possible in the hull; 2. No boat heeling (reaching), bodyweight in front of the seat; 3. No boat heeling (reaching), bodyweight at the back of the seat. A biomechanical analysis was made in order to estimate the forces on the body in the three boat conditions where the boat heeling and the position of the bodyweight of the sailor are varied. An iterative design process was followed which resulted in different prototypes and finally in a new seat.
RESULTS: The main requirement on the seat is that it should prevent sliding on the seat in the frontal plane, especially in condition 1. Then, a friction coefficient of 0,63 is needed. Three prototypes have been build and tested. The final design consists of an aluminium seat with three sloping surfaces and a backrest that stabilizes the body. The seat can slide 19 cm forwards and backwards.
CONCLUSION: The third prototype has been tested in the lab and on the water. Freedom of movement and stability were enhanced. The prototype is further developed and applied for different Paralympic sailors and sailboats.

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1. Introduction

Sailing the 2.4mR, a Paralympic class sailing boat (single-hander) is very strenuous for the body. Sailors of the Dutch Paralympic sailing team experienced several injuries in the past years. One of the sailors of the team is a 39 year old man with diastrophic dysplasia, a disorder of cartilage and bone development. This man has a short stature with very short arms and legs and joint deformities which restrict movement. Facing the bow of the boat, his main tasks are handling the rudder and the main sheet with his hands, shown in figure 1. He described his injuries as "overall pain in the joints, mainly lower spine, hips, knees and shoulders". The sailor and coach assumed the pain was caused by insufficient stability provided by the standard seat of the boat. This seat

* Corresponding author. Tel.: +31 70 4458345;
E-mail address: k.l.vanstein-callenfels@hhs.nl

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(including backrest) is attached to the bottom of the boat. It cannot compensate for any movements of the boat e.g. by counter movements or cushioning. While reaching (no boat heeling), for optimal boat stability, and thus performance, the sailor wants to be able to position his body more to the bow (front) or the stern (back), depending on the circumstances.

Using the standard seat, moving to the bow of the boat is only possible when contact with the backrest is lost. For the stability of the boat during sailing close hauled (maximum boat heeling), the sailor wants to position his bodyweight to the windward side of the boat. The combination of a seat at an angle with a slippery surface likely results in side slipping of the sailor to the lower side of the boat while sailing close hauled. To prevent slipping away, the sailor uses his whole body (hands, arms, shoulders, knees) to find support, which restricts the handling tasks, costs valuable energy, causes highly tensed muscles and might be the cause of the injuries. The design goal for this project was to find an optimum in body stability and range of motion during sailing.

Figure 1. The 2.4mR under sail (left) and a view in the cockpit (right).

2. Methods

Optimizing the standard seat and backrest was done by biomechanically analysing the movements and support of the body during sailing. An analysis of the possible movements (range of motion) of the skipper and the boat was made using a mock-up of the boat's cockpit in the frontal and sagittal plane. A movement analysis of sailing was made in three boat conditions depending on the boat orientation (heeling) and the position of the body in the boat in the frontal and the sagittal plane (table 1).

Table 1. The three test conditions, depending on boat orientation and body position.

Condition	Boat orientation	Body position frontal plane	Body position sagittal plane
1	Heeling 32° (sailing close hauled)	As much windward as possible in the cockpit	back of the seat, leaning on the backrest
2	No boat heeling (reaching)	middle of the seat	front of the seat, no support of the backrest
3	No boat heeling (reaching)	middle of the seat	back of the seat, leaning on the backrest

The boat can change position depending on the wind direction and course. Test condition 1 can occur with the portside of the boat windward (A) or starboard side of the boat windward (B). Figure 2 shows the main points of body support in condition 1 for situation A and B. In both situations, the knee on the lowest or 'leeward' side of the boat is put on the hull of the boat, the 'windward' shoulder and one hand on the frame of the deck. For the body, this condition is the most demanding, it can take approximately 15 minutes until the boat (and therefore the body) changes position. When the course of the boat is approximately the same as the wind direction, the boat has to zig-zag (tacking). Situation A and B follow up each other constantly.