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# EXAMINATION OF SAILORS' BALANCING ABILITY CONSIDERING THE ROLE OF THE HEAD MOVEMENT

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## 1. Introduction

Human is an unstable system unless a control system is continuously acting [1]. This control system is characterized by the balancing ability. The present study examines the dynamic balancing ability using ultrasound-based provocation tests.

Three major sensory systems are involved in balance: vision, the vestibular system, and the somatosensory system. When upright human stance is perturbed, the vestibular system in the inner ear transmits the related signals to the brain. In the study, the movement of the head was considered as a crucial determinant of the balancing capability. The head is a natural frame of reference for action since it contains the two most important perceptual systems for detection of self-motion relative to space, the visual and vestibular systems [2].

During sailing the sportsmen have to face a continuously changing environment. This could be responsible for establishing a common sailor balancing ability. The present study aims to determine differences in the dynamic balancing method of professional sailors compared to the method of a non-sailor control group.

## 2. Methods

### 2.1 Subjects

Subjects involved in the study were professional sailors, who have been competing in sailing in at least the last 3 years, and a non-sailor control group, who haven't competed in any sports. Exclusion criteria were locomotor disorders for both groups.

The sailor group included 3 women and 8 men (n = 11; average age: 17.73±3.32 years; average height: 171.95±10.63 cm; average body mass: 66.85±12.23 kg). The control group consisted of 3 women and 8 men (n = 11; average age: 20.91±1.45 years; average height: 176.32±10.81cm; average body mass: 76.47±22.37 kg). Each subject provided informed written consent to participation in the tests and information about their sailing/sporting practice (duration, regularity, best results on sailing competitions (only for the sailor group), injuries of the locomotor system)

### 2.2 Experimental protocol

Balancing capacity after sudden perturbation was modelled using a PosturoMed© (Haider-Bioswing, Weiden, Germany) device (Fig. 1). The rigid platform (60 cm × 60 cm) is connected to a rigid frame by 8 steel springs with identical strength. The number of working springs (4, 6, or 8 springs) can regulate the displacement characteristics of the platform. The four-spring system was selected for use with both groups. The movement of the platform was recorded with Zebris© (ZEBRIS GmbH, Isny, Germany) CMS 10 system using active single ultrasound-based markers attached to the side of the platform. The measuring frequency was 50 Hz. The recorded coordinates of the platform were documented on computer using the original WinPosture (Zebris MedizinTechnik, Germany) software. The details of measuring method could be found in [3]. The movement of the subject's head was recorded by the Optitrack Motion Capture camera system (NaturalPoint, Inc. DBA OptiTrack), consisting of 18 calibrated cameras (Flex 13). The subject wore a well-fixed safety helmet, to which markers were attached (Fig. 1). The cameras recorded the 3D-coordinates of the markers at a frequency of 120 Hz, which were documented by the original Motive© (NaturalPoint, Inc. DBA OptiTrack) software and exported by the Fukuda gait test measuring software (developed in our motion lab). The two software were synchronized.

Prior the measurement the platform was moved 20 mm in medio-lateral direction and locked by a fastening/provocation unit. By releasing the unit, the plate swings back into its resting position (Fig 1). The participant should counterbalance this sudden disturbance, so that the oscillated device with a participant on it is a damped system [3]. The measurements involved the standardized double-limb position with eyes closed on the plate with 4 working springs.

### *2.3 Data processing and statistical analysis*

Raw measurement data was exported from the WinPosture and Fukuda software and processed by a Wolfram Mathematica (Wolfram©, v11.0) algorithm (developed in our lab). From the processed data, the parameters were calculated with the use of Wolfram Mathematica (Wolfram©, v11.0) and Matlab (MathWorks©, R2014a) algorithms (developed in our lab). The considered parameters were:

- *HeadYMinmax* and *HeadXMinmax*: The difference between the maximum and minimum values of the head coordinates in *Y* (antero-posterior: *AP*) and *X* (medio-lateral: *ML*) directions.
- *PlatYMinmax* and *PlatXMinmax:* The difference between the maximum and minimum values of the platform coordinates in *Y* and *X* directions.
- *AbsDiffMax_Y* and *AbsDiffMax_X:* The difference of the head and platform coordinates (both *X* and *Y*) were calculated for the whole measurement. The absolute maximum of these differences were considered as parameters.

For each parameter, the mean and standard deviation were calculated. To separately test the between subject effect of each parameter univariate test results were also considered in the evaluation. Level of significance was set to *p=0.05*. The statistical analysis was carried out using IBM SPSS Statistics 22® software.

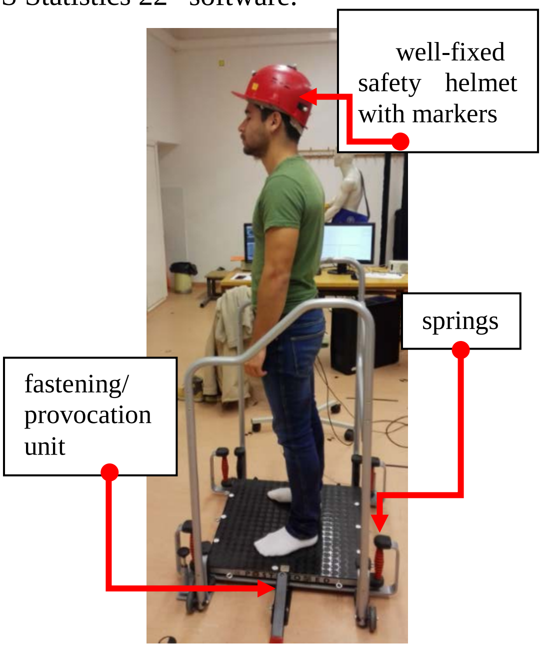


**Fig. 1.** Double-limb standing with eyes closed on the PosturoMed© device

## 3. Results

Some measurements had to be excluded from the study, because of the errors of the ultrasound based measuring system. The measurements could be evaluated for 7 sailors and 11 control people.

Considering the *HeadYMinmax* parameter, significant difference (*p=0,039*) shows between the sailor and the control group (Tab. 1.). The magnitude of the head movement in *AP* direction was significantly larger in the sailor group.

| Parameter | Sailor group - Mean (SD) | Control group - Mean (SD) | Between subject effect - *p* | Observed Power |
|---|---|---|---|---|
| *HeadXMinmax* | 18,93 (3,27) | 23,32 (2,96) | ,334 | ,156 |
| *HeadYMinmax* | 25,19 (3,44) | 14,88 (3,11) | **,039** | ,557 |
| *PlatXMinmax* | 34,04 (0,52) | 32,67 (0,47) | *,068* | ,451 |
| *PlatYMinmax* | 5,54 (0,96) | 5,52 (0,87) | ,984 | ,050 |
| *AbsDiffMax_X* | 22,48 (2,90) | 24,19 (2,63) | ,666 | ,070 |
| *AbsDiffMax_Y* | 23,10 (3,61) | 13,85 (3,26) | *,073* | ,436 |

**Tab. 1.** Results of statistical analysis (**Bold**: significant difference, where $p < 0.05$)

## 4. Remarks

The increasing magnitude of the head movement means, that the sailor group actively interfered with the *ML* oscillation by moving their heads in *AP* direction. This could show a more advanced balancing ability in the case of the sailor group. The balancing method of the sailor group and the control group is significantly different.

## Acknowledgements

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## References

[1] D. A. Winter, Human balance and posture control during standing and walking, Gait&Posture, 3, 1995. pp. 193-214.

[2] Pozzo, T., Berthoz, A., & Lefort, L., Head Stabilization during Various Locomotor Tasks in Humans. 1. Normal Subjects. Experimental Brain Research, 82(1), 1990. pp. 97-106.

[3] R. M. Kiss, A new parameter for characterizing balancing ability on an unstable oscillatory platform, Medical Engineering & Physics, 33, 2011. pp. 1160-1166.