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# INTEGRATED SIMULTANEOUS DIAGNOSIS IN WATER SPORTS: CONCEPT AND CASE STUDY

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## INTRODUCTION

Performance in water sports is influenced by biomechanical, physiological, and kinesiological parameters. While these factors are well-documented in precise disciplines such as rowing and sprint canoeing, Olympic canoe slalom remain less explored in this regard. Performance in canoe slalom involves navigating 18 to 25 gates placed on whitewater as quickly as possible. The duration of the effort typically ranges from 80 to 120 seconds and is performed at submaximal to maximal intensity (Nibali, Hopkins & Drinkwater, 2011). Competitions are held in two boat classes: men's and women's single canoe (C1) and kayak (K1).

In all the water sports, diagnostic procedures are typically applied separately and in isolation, lacking an integrated perspective on overall performance. Moreover, diagnostic assessments are not conducted directly on the water but rather in a laboratory setting. A comprehensive on-water diagnostic approach would allow for real-time insight into key biomechanical (kinematic and dynamic), physiological, and kinesiological interrelations, thereby facilitating the accurate identification of individual performance-limiting factors. In this paper, we introduce a newly emerging concept of integrated simultaneous diagnosis in canoe slalom, illustrated through a case study. Longitudinal testing will provide deeper insights into the specific characteristics and demands of performance in canoe slalom.

## METHODS

During a highly reliable (ICC = 0.96) sport-specific 12x15m-All-Out-Shuttle-Test, which corresponds in duration to actual race performance and shows a strong correlation ($r = 0.70 - 0.87$; $p < 0.01$) with competition results (Vajda & Piatrikova, 2022; Vajda et al., 2023), we simultaneously diagnose several key parameters to gain a comprehensive understanding of the athlete's performance. The test was recorded on video, and the time was measured from the footage with an accuracy to the hundredth of a second (Figure 1).

These include dynamic and kinematic performance parameters such as paddle force, force impulse, force curve, acceleration, speed, and resistive braking forces. Spiroergometric parameters were assessed via METAMAX 3B, Cortex®, Germany (www.cortex-medical.com), including oxygen consumption, ventilation, heart rate (Polar, www.polar.com) and respiratory rate. Muscle oxygenation was measured via MOXY® (www.moxymonitor.com). The lactate concentration was also determined (Blood Lactate Meter LT 1730 Pro 2; Arkray; www.arkray.eu) in the fifth minute after completing the test.

This simultaneous diagnosis was preceded by an analysis of body composition (InBody 970S; www.uk.inbody.com) and anthropometric parameters correlated with performance in canoeing. (Ridge et al., 2007; Akca & Muniroglu, 2008), ensuring a holistic assessment of the athlete's physical and physiological state. The diagnostic assessment was conducted on a well-trained C1 male athlete (age: 35 years) classified as Tier 3 (National Level) according to the categorization by McKay et al. (2021).

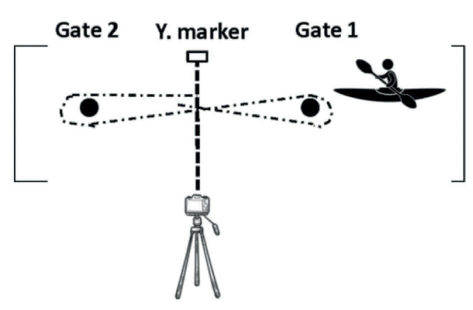


**Figure 1:** Testing protocol according to Vajda & Piatrikova (2022)

**Figure 2:** Instrumental methods monitoring biomechanical and physiological parameters.

**Figure 3:** Course of the 12x15m All-Out Shuttle Test with Turns according to Vajda and Piatrikova (2022)

## RESULTS

We present the results provided by the simultaneous diagnosis method on a model canoeing performance. An athlete with the given morphological characteristics (Figure 4) completed the test in 117.93 seconds.

| | | | |
|---|---|---|---|
| **Body height** | 192 cm | Flexed biceps girth | 37.5 cm |
| **Body weight** | 94 | Flexed forearm girth | 34 cm |
| **Body fat (%)** | 10.3 % | Chest girth | 118 cm |
| **Fat free mass** | 83.8 kg | Arm span | 208.5 cm |

**Figure 4:** Morphological parameters of the model athlete.

The tensiometric data synchronized with video analysis provides a detailed record of force application, force impulse, as well as vertical and horizontal acceleration. Over time, the recordings reveal a decline in velocity, which corresponds to a decrease in stroke frequency (from 72 to 52 strokes/minute), peak stroke force (from 233 to 140 N), and stroke force impulse (from 7.55 to 4.97 kg.s-2).

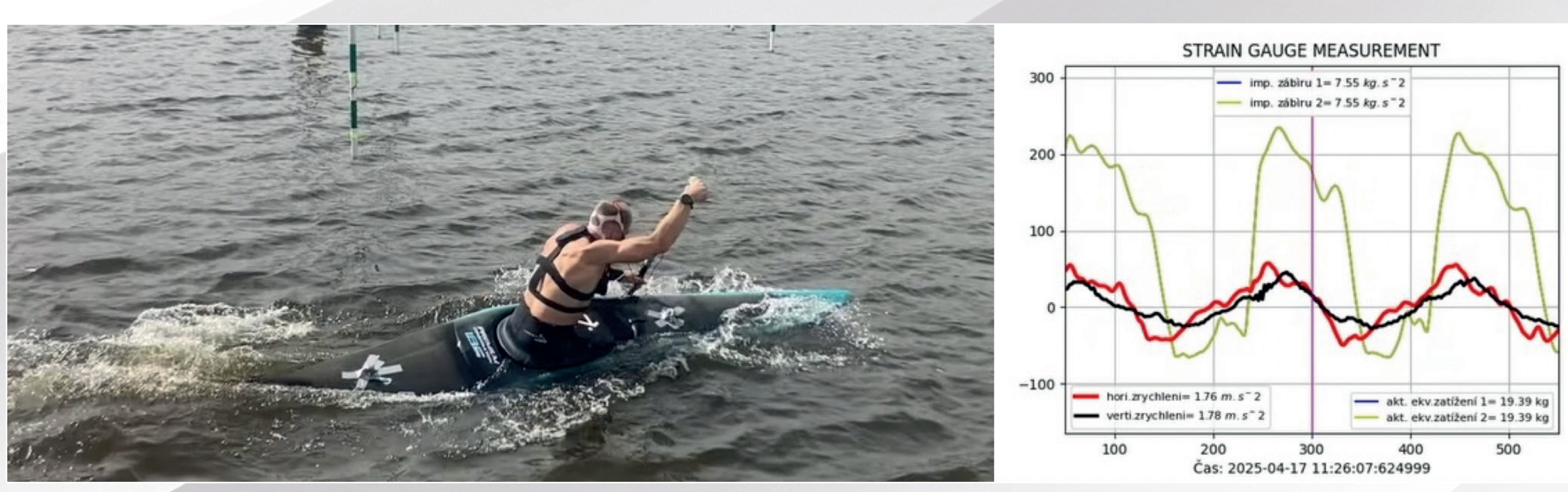


**Figure 5:** The tensiometric data synchronized with video analysis.

In Figures 5 and 6, the progression of physiological parameters during the test is presented. Respiratory rate (BF) closely corresponds with stroke frequency—both show a decreasing trend. In contrast, respiratory volume per breathe (VT) increases, compensating for the reduced BF.

| Time/Variable | V'O2 | V'O2/kg | V'CO2 | V'E | VT | BF | RER | HR |
|---|---|---|---|---|---|---|---|---|
| 0:09:50 | 0,7 | 7 | 0,85 | 32,9 | 0,81 | 40 | 1,21 | 81 |
| 0:10:00 | 0,93 | 10 | 1,08 | 42,1 | 0,59 | 72 | 1,16 | 105 |
| 0:10:10 | 1,95 | 21 | 1,97 | 66,2 | 1,07 | 62 | 1,01 | 133 |
| 0:10:20 | 3,22 | 34 | 3,33 | 99,2 | 1,63 | 61 | 1,04 | 146 |
| 0:10:30 | 3,29 | 35 | 3,82 | 116,5 | 2,08 | 56 | 1,16 | 152 |
| 0:10:40 | 3,67 | 39 | 4,58 | 143 | 2,35 | 61 | 1,25 | 157 |
| 0:10:50 | 3,87 | 41 | 4,95 | 152,3 | 2,74 | 56 | 1,28 | 162 |
| 0:11:00 | 3,63 | 39 | 4,59 | 136,1 | 2,58 | 53 | 1,27 | 164 |
| 0:11:10 | 4,01 | 43 | 5,29 | 158,4 | 3,11 | 51 | 1,32 | 165 |
| 0:11:20 | 3,75 | 40 | 4,94 | 153,1 | 2,89 | 53 | 1,32 | 166 |
| 0:11:30 | 3,82 | 41 | 5,13 | 159,5 | 2,99 | 53 | 1,34 | 167 |
| 0:11:40 | 3,85 | 41 | 5,16 | 161,5 | 3,08 | 52 | 1,34 | 168 |
| 0:11:50 | 4,02 | 43 | 5,26 | 162,4 | 3,23 | 50 | 1,31 | 169 |
| 0:12:00 | 3,95 | 42 | 5,17 | 159,7 | 3,1 | 52 | 1,31 | 169 |
| 0:12:10 | 3,91 | 42 | 5,07 | 152 | 3,5 | 43 | 1,3 | 170 |

**Figure 6:** Physiological parameters and their progression throughout the test.

These are relatively high values of physiological parameters, especially considering that the activity involves only the upper body—and is further limited to unilateral movement on the left side.

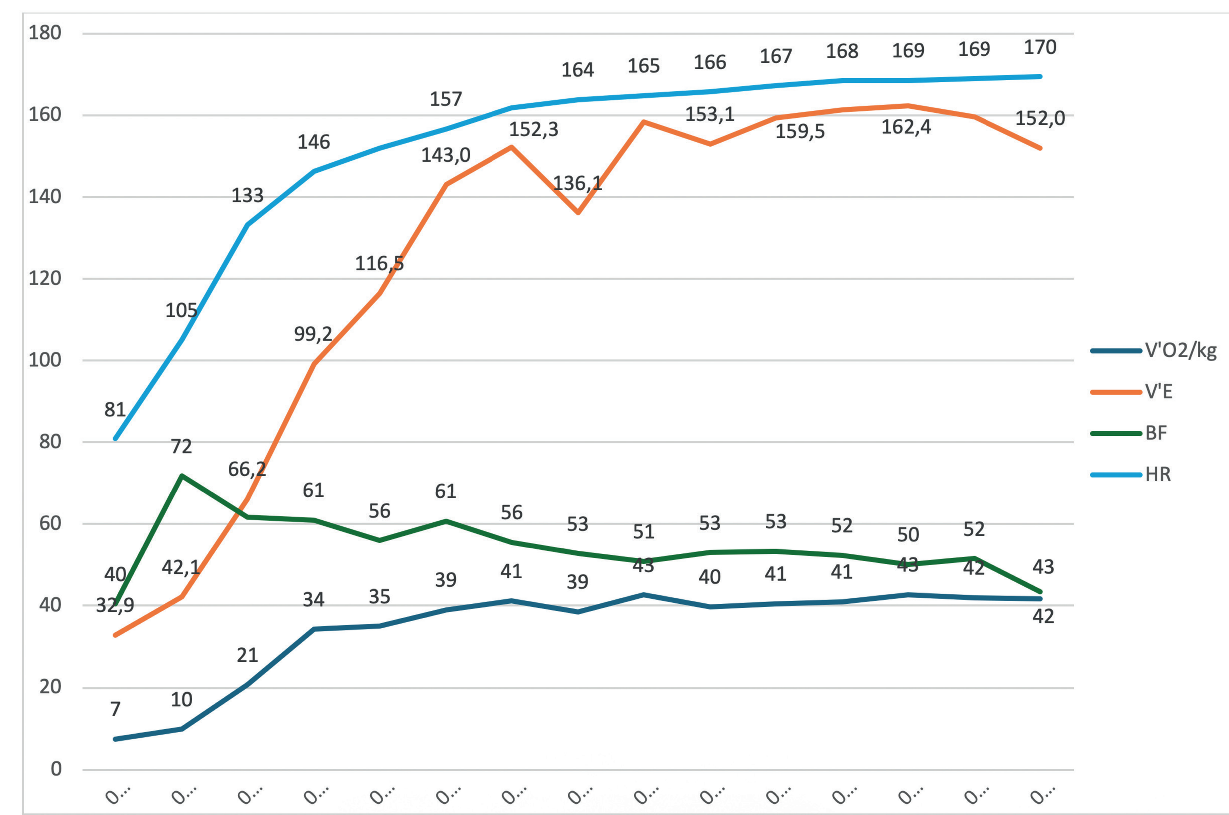


**Figure 7:** Graphical representation of the physiological responses—heart rate, oxygen uptake, respiratory rate, and ventilation—during the 12x15m All-Out Shuttle Test.

Unfortunately, the MOXY® oximetry data were not usable. Forearm muscle oxygen saturation dropped to zero within the first 30 seconds - the device is not calibrated for the given activity. In the fifth minute after completing the test, a lactate sample was collected, revealing a final lactate concentration of 10.9 mmol/l-1.

## DISCUSSION

Integrated simultaneous diagnosis is still in its early stages; currently, it is a concept that we are refining and validating through pilot measurements in rowing, sprint canoeing, and whitewater canoeing. At present, it is technically, time-wise, and personnel-intensive. The refinement of this new method should eventually enable efficient athlete assessment according to a precisely defined protocol within a timeframe not exceeding two hours. It is necessary to conduct dozens of additional measurements across all boat classes and age categories for both males and females.

The model athlete lagged significantly behind the Slovak U23 national team athletes in terms of test completion time, with their average performance reported at 104.36 ± 3.67 seconds (Vajda et al., 2023). This discrepancy can be partially attributed to the presence of measurement equipment, which not only hinders optimal gate navigation but also increases the overall weight of the athlete. Additionally, a lower level of sport-specific conditioning likely contributed to the slower time. Despite the unusability of the MOXY data, we were able to successfully carry out an accurate description of the athlete's baseline condition, which can serve as a foundation for subsequent training planning.

## CONSLUSIONS

Integrated simultaneous diagnosis is an effective tool that enables the identification of specific canoe slalom performance limitations, which can serve as a basis for optimizing movement efficiency and thereby enhancing the athlete's performance. Following technological refinement of the measurement procedures, this represents a valid and reliable concept. However, its full value will only be realized after testing dozens of additional athletes, which will enable the development of normative data and, consequently, allow for interindividual comparisons.

## ACKNOWLEDGEMENTS

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