

## FACTOR STRUCTURE OF SPECIFIC TEMPORAL AND NOTATIONAL BIOMECHANICAL VARIABLES FOR EVALUATING KAYAK PADDLING TECHNIQUE IN WHITEWATER SLALOM

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### Abstract

*This study aims to identify the performance differences in negotiating the upstream gates between two kayakers during their second run in the qualifiers at the 2004 Athens Olympics by determining the factor structure. The research focuses on the best Macedonian kayaker, Lazar Popovski, who placed fifth in the second run, and the Swiss kayaker, Michael Kurt, who was ranked first in the second run. Both elite competitors successfully navigated all gates without penalties. Initially, a comparison was made regarding the kinematic and biomechanical variables in negotiating the course through video and electronic recordings. Component factor analysis was applied to determine the latent structure of the variables, where the criterion for retaining significant principal components is the Kaiser-Guttman criterion. Three latent factors were extracted for both kayakers in the second run. For Kurt, five latent variables were isolated in the first general factor, and two variables each in the second and third factors. Popovski's first general factor contains six latent variables, and one variable each in the second and third factors. The characteristic variables pertain to the duration of the paddle in the water, stroke frequency, and the number of strokes between gates. The values obtained from the research should help the kayakers and their coaches identify where and why they lose time in negotiating the upstream gates. These parameters provide data for planning the training process and race analysis.*

**Key Words:** *latent factors, stroke frequencies, paddle immersion, number of strokes*

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### Introduction

White-water kayaking is one of the most challenging kayaking disciplines, encompassing flat water disciplines from solo to eight-person boats, as well as whitewater disciplines in single and double boats, both downriver and canoe/slalom. A standard slalom course measures between 250 to 300 meters, with gates ranging from a minimum of 15 to a maximum of 25, including 6 upstream gates, which are the most difficult to navigate and are the focus of our research. The best Macedonian kayaker, Lazar Popovski, has participated at four Olympic Games, the latest being in Athens in 2004. Research was conducted based on video recordings of both runs, specifically analyzing Popovski's second run in comparison to the first-place finisher, Michael Kurt from Switzerland. The analysis includes kinematic and biomechanical notational variables to determine the efficiency comparison between Popovski and Kurt in negotiating the upstream gates.

The aim of the research is to establish the differences in the factor structure between the two kayakers concerning temporal and notational variables.

There is a limited number of publicly available publications in the field of notational, biomechanical, and kinematic performance analysis. Previous studies have focused on parameters related to improving kayaking performance, including visualization skills (Males et al., 1998; White & Hardy, 1998), mental preparation (Males & Kerr, 1996), energy systems (Zamparo et al., 2006), morphological characteristics of elite slalom kayakers (Norton & Olds, 1996; Ridge et al., 2007), the impact of paddle strength (Sperlich & Klauck, 1992), and equipment positioning (Ong et al., 2005).

This research represents the first of its kind in Macedonia. The objective of the research was to determine the factor structure of relevant kinematic and notational variables during the second run in Athens 2004.

**Material & methods**

The sample of subjects consists of two elite kayakers, Lazar Popovski and Michael Kurt, who participated in the 2004 Athens Olympics. Michael Kurt was ranked first in the second run, while Lazar Popovski was fifth. Lazar Popovski, born in 1975, is the best and most successful kayaker in Macedonia. He has participated in World and European Championships and four Olympic Games: 1992 in Barcelona, 1996 in Atlanta, 2000 in Sydney, and 2004 in Athens, achieving significant results. In Athens, in the K-1 slalom discipline, he finished sixth in the qualifying round, advancing to the semi-finals. In the semi-finals, he finished in sixteenth place, failing to reach the top ten spots and the final event. Michael Kurt, born in 1980, is a Swiss competitor who has participated in European and World Championships, winning medals.

In the research, due to the specific nature of the sport discipline of slalom kayaking, a total of 34 kinematic and biomechanical notational variables are presented. Due to the extensive number of variables, this paper presents the variables that were isolated and presented through factor analysis while negotiating the six upstream gates on the course.

The software used for video playback of the paddling was Kinovea (Kinovea 0.9.1.). The analysis was conducted by an individual with several years of experience in this sport.

To achieve the subject and aim of the research, component factor analysis was applied to compare the kayakers Lazar Popovski and Michael Kurt. To determine the significance of the principal components, the Kaiser-Guttman criterion was applied, where all components with an eigenvalue of 1 (one) are considered significant. In the subsequent step, the non-rotated factor matrix was rotated with an orthogonal solution using Varimax orthogonal rotation. When defining the factors, only those with an absolute value greater than 0.300 were taken into account. The SPSS 20 software was used for data

**Results**

*Factor Structure of Variables from Michael Kurt's Second Run*

From the three main components presented in Table 1, the first principal component, with an eigenvalue of 5.05, explains 56.08% of the total variance of the significant principal components. The second component, with an eigenvalue of 2.27, explains 25.23% of the total variance, and the third component, with an eigenvalue of 1.25, explains 13.95% of the total variance. All extracted components together explain 95.267% of the total variance of the significant components.

Table 1. Significant eigenvalues (Total), percentage of total variance of significant principal components (%TotalVariance) and cumulative percentage of total variance of significant principal components (Cumulative %).

Total Variance Explained			
Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	5.048	56.084	56.084
2	2.271	25.234	81.318
3	1.255	13.949	95.267

Table 2. Communalities of the kinematic and notational variables

Communalities		
Second Run / Michael Kurt	Initial	Extraction
Number of strokes with the right hand between gates	1.000	<b>.978</b>
Duration of the right paddle in water	1.000	.939
Number of strokes with the left hand between gates	1.000	.931
Duration of the left paddle in water	1.000	.858
Total number of strokes with both hands between gates	1.000	.971
Duration of paddle in water between gates	1.000	.969
Average frequency of strokes between gates	1.000	<b>.991</b>
Average frequency of strokes with the right hand between gates	1.000	.977
Average frequency of strokes with the left hand between gates	1.000	<b>.960</b>

Table 2 represents the extent of explained variance of each individual element by the defined significant principal components, i.e., the size of communalities of the variables. It can be noted that the variable "number of strokes with the right hand between gates" has the highest value in the first component ( $h^2=.978$ ), the variable "average frequency of strokes between gates" has the highest value in the second component ( $h^2=.991$ ), and the variable "average frequency of strokes with the left hand between gates" has the highest value in the third component ( $h^2=.960$ ).

From the results in Table 3, the first principal - general component is defined by the variables: number of strokes with the left hand between gates, duration of the right paddle in water, number of strokes with the left hand between gates, total number of strokes with both hands between gates, and duration of paddle in water between gates. The second component is defined by the variables: average frequency of strokes between gates and average frequency of strokes with the right hand between gates. The third component shows significant saturations with the variables: duration of the left paddle in water and average frequency of strokes with the left hand between gates.

Table 3 Projections of elements onto defined components

Rotated Component Matrix <sup>a</sup>			
BTOPO BO3EHE/KYPT Varimax	Component		
	1	2	3
Number of paddle strokes with the right hand between gates	<b>.783</b>	.593	-.109
Duration of the right paddle in water	<b>.926</b>	.254	-.129
Number of paddle strokes with the left hand between gates	<b>.706</b>	.092	.651
Duration of the left paddle in water	.418	-.296	<b>.771</b>
Total number of paddle strokes with both hands between gates	<b>.851</b>	.450	.212
Duration of the paddle in water between gates	<b>.954</b>	.083	.227
Average frequency of paddle strokes between gates	.201	<b>.945</b>	.240
Average frequency of paddle strokes with the right hand between gates	.290	<b>.909</b>	-.258
Average frequency of paddle strokes with the left hand between gates	-.172	.137	<b>.955</b>

#### Factor Structure of Variables from Lazar Popovski's Second Run

The results from Table 4, indicate that the first principal component, with an eigenvalue of 4.59, explains 50.96% of the total variance of the significant principal components. The second component, with an eigenvalue of 2.82, explains 31.39%, and the third component, with an eigenvalue of 1.2, explains 13.35% of the total variance of the significant principal components. Together, these three extracted components explain 95.7% of the total variance.

Table 4

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	4.587	50.963	50.963
2	2.825	31.390	82.353
3	1.201	13.349	95.702

Results from Table 5, show the communalities of the variables. We observe that the variable with the highest value in the first component is the average frequency of strokes between gates ( $h^2=.986$ ), in the second component it is the variable duration of paddle in water between gates ( $h^2=.979$ ), and in the third component the highest value is for the variable duration of left paddle in water ( $h^2=.962$ ).

In Table 6, saturations of variables on the principal components are presented, indicating that the first principal component is defined by the variables number of strokes with the right hand between gates, number of strokes with the left hand between gates, total number of strokes with both hands between gates, average frequency of strokes with the right hand between gates, and average frequency of strokes with the left hand between gates. The second principal component is saturated with the variables duration of the right paddle in water and duration of paddle in water between gates, while the third principal component is defined by the variable duration of the left paddle in water.

Table 5. Communalities of kinematic and notative variables

Communalities		
ВТОРО ВОЗЕЊЕ/ПОПОВСКИ	Initial	Extract ion
Number of strokes with the right hand between gates	1.000	.933
Duration of the right paddle in water	1.000	.972
Number of strokes with the left hand between gates	1.000	.946
Duration of the left paddle in water	1.000	<b>.962</b>
Total number of strokes with both hands between gates	1.000	.982
Duration of paddle in water between gates	1.000	<b>.979</b>
Average frequency of strokes between gates	1.000	<b>.986</b>
Average frequency of strokes with the right arm between gates	1.000	.945
Average frequency of strokes with the left arm between gates	1.000	.909

Table 6. Saturations of variables on the principal components

Rotated Component Matrix <sup>a</sup>			
Second run/Popovski Varimax	Component		
	1	2	3
Number of paddle strokes with the right hand between gates	<b>.864</b>	.426	.070
Duration of the right paddle in water	.018	<b>.985</b>	-.031
Number of paddle strokes with the left hand between gates	<b>.793</b>	.255	.502
Duration of the left paddle in water	-.031	.019	<b>.980</b>
Total number of paddle strokes with both hands between gates	<b>.875</b>	.362	.293
Duration of the paddle in water between gates	-.007	<b>.755</b>	.640
Average frequency of paddle strokes between gates	<b>.931</b>	-.196	-.284
Average frequency of paddle strokes with the right hand between gates	<b>.844</b>	-.075	-.477
Average frequency of paddle strokes with the left hand between gates	<b>.897</b>	-.322	.007

Analysing the saturation of variables on the principal components from the perspective of ecological dynamics, which emphasizes the interaction between individuals and the environment (water) (Button et al., 2021), it can be noted that the techniques (coordination) of the kayakers in relation to the water (interaction with the environment) are different. This is evident from the variables that define the principal components.

### Dicussion

Three latent factors were extracted from the two kayakers in the second run. Kurt isolated five latent variables in the first common factor and two variables each in the second and third factors. Popovski's first common factor contains six latent variables and one each in the second and third factors. The characteristic variables refer to the duration of paddle in the water, the frequency of strokes, and the number of strokes between the gates.

The values obtained from the research should help the kayakers and their coaches identify where and why they are losing time in overcoming the opposing gates. These parameters provide data for planning the training process and analyzing the races.

The research has several limitations due to the small sample size of elite athletes, a limited number of variables including temporal and notational variables instead of kinematic and kinetic variables, and variables of other nature. Additionally, video analysis was performed by one person, which may affect the objectivity of the results, among other factors.

### Conclusions

Applying principal component factor analysis to the initial paddling of Kurt and Popovski, three main components were extracted. However, due to the different variables defining the principal components, it

can be observed that the technique (coordination) concerning the environment for these two kayakers is different.

This approach to analyzing slalom kayak races can also be used to examine technique in subsequent paddling on the same course, revealing changes in interaction with the environment over time. Furthermore, comparisons can be made between kayakers with different performances, ages, genders, etc.

### **References**

- IOC HANDBOOK OF SPORT & SCIENCE, Canoeing, First Edition. Edited by Don McKenzie and Bo Berglund. © 2019 International Olympic Committee. Published 2019 by John Wiley & Sons Ltd.133
- Hunter, A. (2009) Canoe slalom boat trajectory while negotiating an upstream gate. *Sports Biomech*, 8(2), 105–113. doi: <https://doi.org/10.1080/14763140902934837>

