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Keywords

sailing, motor abilities, sailing performance, DEMATEL, sailing tactics, sport result

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Article

Relationship between motor skills and various sailing skills and sports performance – study using the DEMATEL approach

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Abstract: Introduction. The purpose of this paper is to determine the mutual relation between various motor abilities and factors of sailing performance. Material and methods: 25 sailors from the Polish national team in sailing Olympic classes were asked to fill a questionnaire concerning the influence of various motor abilities and sailing performance factors on the result. In total, 5 sailors participated in the study by returning properly filled questionnaires. To determine the relationship between the motor abilities and sailing performance factors, the DEMATEL method has been utilized. Results: In terms of motor abilities, mobility is the most significant factor, and muscle strength is the most dominant factor in terms of cause, and quickness in terms of effect. In terms of sailing performance, mental fitness is the most significant factor, and tactical knowledge is the most dominant factor as an effect of sailing performance and knowledge of racing rules as a cause. Conclusions: In the group of factors of sailing performance, mental fitness and tactical knowledge are the most important. Therefore, there should be more focus on improving the training process of these two factors.

Keywords: sailing, motor abilities, sailing performance, DEMATEL, sailing tactics, sport result.

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1. Introduction

Motor abilities are an essential factor of success in various sports disciplines, such as gymnastics [1], football [2], dancing [3], and numerous others [4–6]. Olympic sailing, due to its characteristics and competitiveness, requires a great variety of skills and abilities, which include motor abilities, technical skills, and knowledge concerning the sailing technique and boat parameters, meteorological knowledge, knowledge of sailing tactics, mental fitness, and knowledge of racing rules [7, 8]. Moreover, due to physical demand [9] and possible injuries [10, 11], it is essential to train properly to maximize a possibility to achieve higher sailing performance. This can be expressed in the form of focusing on the factors which have a higher influence on the final result. Therefore, it is essential to determine the impact of various elements on performance.

Sailors' performance has been widely discussed in the literature (e.g.: [12–14]). The hiking performance has a strong correlation with the maximal eccentric-isometric knee extensor strength and is weakly related to the maximal trunk extensor muscle [12, 15]; therefore, it is crucial to focus on maximum strength training for adult sailors to increase their isometric knee-extension strength endurance [13]. Physical fitness and muscular strength are important performance factors for Olympic class sailors [9, 16]. However, there are also other factors influencing sailing performance, such as tactical knowledge, sailing technique, equipment, mental fitness, meteorology knowledge, and racing rules knowledge [8, 12, 16–18].

Even though the impact of motor abilities on the performance and result has been widely discussed in the literature (e.g.: [3, 6]), little space has been devoted to the relationship between various elements of motor abilities and elements of sailing performance

(namely: tactical knowledge, sailing technique, equipment, mental fitness, meteorology knowledge, and racing rules knowledge) [8, 12, 16–18] and the results. Previous studies conducted in this matter [8] proved that, depending on the level of proficiency, the mutual relation between various elements of sailing performance and motor abilities may vary [8]. The higher the proficiency level is, the higher the importance of elements such as tactical knowledge, equipment, racing rules knowledge, and mental fitness [19, 20]. Mental fitness is perceived as a set of following skills: total commitment to pursuing excellence, setting practice goals, competition simulation, mental imagery, focusing and coping with distractions, detailed competition plans, positive thoughts, and post-competition evaluations [21, 22].

Factors of the sailing performance have a direct impact on the sport result [8] although no study showed the mutual relation between factors and the significance of each factor. Therefore, the main purpose of this paper is to clarify and determine the influence and significance of various factors of sailing performance on the sport result. To achieve this goal, based on the above-mentioned research [8, 19, 20], the following hypothesis has been adopted.

Hypothesis: Tactical knowledge is the most significant and dominant factor of sailing performance.

2. Materials and Methods

Participants in this study were experienced sailors, members of the Polish national team of the Polish Yachting Association in the current and future Olympic classes, namely: Laser, Laser Radial, Finn, RS:X, 470, 49-er, 49-er Fx, Nacra 17, iQFOiL. The questionnaires regarding the relationship between various elements of motor abilities and various elements of the sailing performance and the result were sent via the Internet in April and May 2021 to all 25 members of the Polish national sailing team in Olympic classes. 2 participants responded to the first round of the survey, while 3 responded to the second round. All returned questionnaires were filled in properly, yielding a study sample of 5 sailors.

The participants were asked to evaluate relationships between motor abilities factors, namely: endurance, motor coordination, quickness, mobility, flexibility, muscle strength [1, 2, 5, 23] and sailing performance factors, namely: tactical knowledge, sailing technique, equipment, mental fitness, meteorology knowledge, and racing rules knowledge [8, 12, 16–18] using a questionnaire design formed by comparing criteria of each element pair which is shown by numbers from 0 (no influence between elements) to 4 (extreme influence of the first element). Definitions of motor abilities factors are presented in Table 1.

Table 1. Definition of motor abilities factors in the study.

Factor of motor abilities	Definition
quickness	ability to perform movements in the smallest intervals for given conditions [24]
endurance	ability to continue long-term work with required intensity without compromising the effectiveness of activities and maintaining increased resistance to fatigue [24]
motor coordination	ability to perform spatially and temporally complex movements [24]
mobility	ability to use movement apparatus, thanks to mastering basic movement habits [25]
flexibility	ability to move in a joint or combination-joint within an optimal range of motion [24]
muscle strength	ability to overcome external resistance or resist at the expense of muscular effort [24, 26, 27]

The decision-making trial and the evaluation laboratory (DEMATEL) method were developed in the 1970s [28] and have been used for the construction of the cause–effect chain and the analysis of its components. This method is capable of illustrating the overall influence of factors [29], visualizing causal relations [30], and analyzing dependent factors [31]. The method has been applied in many fields, e.g.: supply chain performance [32], risk assessment of cargo ships [33], service quality [34], a strategy of improving senior citizens' participation in recreational sports [35], and problems of power trading [36].

The DEMATEL method, unlike the classical approach based on structural equation modeling (SEM), does not require a large research sample to provide information concerning the causal relationship among variables, the "expert opinion" DEMATEL provides good research results from a small sample [37, 38].

It can be concluded that the DEMATEL method has become a universal method for multi-criteria decision-making problems due to its relatively simple algorithm that can be implemented in the spreadsheet. The implementation of the DEMATEL method can be divided into six steps [32, 39, 40]:

Step 1: Direct relations between the considered factors are determined. The relations between elements will be judged by professionals subjectively using a questionnaire design formed by comparing criteria of each element pair which is shown by numbers from 0 (no influence) to 4 (extreme influence).

Step 2: Based on the pairwise comparison, a direct-relation $n \times n$ matrix is set up, where the main diagonal elements equal 0. Figures inside matrix Z show the influential extent between the elements.

Step 3: A normalized direct-relations matrix and standardized direct-relation matrix **X** is computed.

$$\boldsymbol{X} = \boldsymbol{S} \times \boldsymbol{Z} \tag{1}$$

where:

X – standardized matrix of direct relationships,

$$\boldsymbol{S} = \frac{1}{Max_{1 \le i \le n} \sum_{j=1}^{n} z_{ij}} \tag{2}$$

Z – matrix of direct relationships.

Results obtained in the standardized matrix of direct relationships are an average of expert opinions.

Step 4: The total impact matrix (direct and indirect) is calculated; the following formula is used to determine the matrix:

$$\boldsymbol{T} = \boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X})^{-1} \tag{3}$$

where:

T – total impact matrix (direct and indirect),

X – standardized matrix of direct relationship,

I – unit matrix

Element t_{ij} of matrix **T** denotes the direct and indirect impact of indicator i to indicator j.

Step 5: Based on the significance indicator (formula 4) and the relation indicator (formula 5), the causal diagram is drawn.

$$S_{ij} = D_{ij} + C_{ij} = \sum_{j=1}^{n} t_{ij} + \sum_{j=1}^{n} t_{ij} \tag{4}$$

$$R_{ij} = D_{ij} - C_{ij} = \sum_{j=1}^{n} t_{ij} - \sum_{j=1}^{n} t_{ij} \tag{5}$$

where:

S_{ij} – the significance indicator,

R_{ij} – the relation indicator,

D_{ij} – total amount of each row,

C_{ij} – total amount of each column,

t_{ij} – total (direct and indirect) influence from indicator i to indicator j,

n – number of indicators.

The causal diagram uses (D + R, D – R) as ordered pairs. The horizontal axis is dedicated to the significance indicator, while the vertical axis is dedicated to the relation indicator. Elements located above the horizontal axis are the cause, while elements below the horizontal axis are the effect in the cause–effect chart. Therefore, this method allows presenting causality of the elements as a simple and clear structure [32].

In some situations, the causal diagram would be too complex if all the relationships were considered [40]. Therefore, the threshold value α should be set to filter out negligible effects. The elements from matrix **T** which are greater than the threshold value should be selected for the causal diagram. Threshold value α is calculated as an average of all elements in the matrix **T** [41]. A more complex approach to calculating the threshold value is based on an entropy concept using the maximum mean de-entropy algorithm [42]. The more components are taken into consideration, the smaller differences of threshold value obtained from both methods are – with at least six components, the results are very similar [42]. Therefore, to simplify the calculation, the method of calculating the average of all elements in matrix **T** has been selected to calculate the threshold value.

Step 6: The importance weights for criteria is calculated:

$$w_i = \frac{d_i + c_i}{\sum_{i=1}^{n} d_i + c_i}, i = 1, 2, \ldots, n \quad (6)$$

where:

w_i – importance weight for i-th criterion,

d_i – total amount of i-th row,

c_i – total amount of i-th column.

DEMATEL is not a standard tool for ranking objects, and utilizing other methods can provide different results. Khazai et al. [43] presented the importance weight of the i-th criterion assigned by the group of experts to correct the structural relation among criteria. A different method of calculating the importance of weight for criteria is based on each factor itself [44, 45], while in the original DEMATEL the importance is calculated on the relationships among factors. The main difference between these two approaches is connected with the necessity the necessity to ask respondents an additional question concerning the importance of each factor itself.

3. Results

In general, the number of sailors in the study was limited; therefore, interpretation of the data should be made with caution, even if all participants of the study were experts and professionals.

The elements of motor abilities as a factor of sailing performance are shown in Table 2. The results presented in Table 3 and Table 7 are an average of the expert's opinions.

Table 2. The factors of motor abilities.

Factor	Motor ability factor
f_1	quickness
f_2	endurance
f_3	motor coordination
f_4	mobility
f_5	flexibility
f_6	muscle strength

The results of the normalized direct-relations matrix **X** for motor abilities are shown in Table 3.

Table 3. Normalized direct-relation matrix **X** for motor abilities (equation 1).

	f_1	f_2	f_3	f_4	f_5	f_6
f_1	0	0.05178	0.1165	0.1942	0.1295	0.1424
f_2	0.1295	0	0.1036	0.2201	0.1424	0.1424
f_3	0.1942	0.1683	0	0.2201	0.1553	0.1295
f_4	0.2201	0.1942	0.2201	0	0.2201	0.1456
f_5	0.1424	0.1295	0.2330	0.1942	0	0.1553
f_6	0.1942	0.1683	0.1812	0.1812	0.1424	0

The total impact matrix **T**, the significance indicator, and the relation indicator are presented in Table 4. The threshold value α is 0.8162; therefore, all values of factors which are greater than the threshold value are presented in the bold type.

Table 4. Total impact matrix **T**, significance indicator, and relation indicator (equation 3).

	f_1	f_2	f_3	f_4	f_5	f_6	D_i+C_i	D_i-C_i
f_1	0.6014	0.5494	0.6915	**0.8248**	0.6626	0.6188	9.1503	-1.2532
f_2	0.7942	0.5619	0.7578	**0.9338**	0.7460	0.6855	8.7727	0.1856
f_3	**0.9343**	0.7793	0.7495	**1.0371**	**0.8389**	**0.7518**	10.1530	0.0288
f_4	**1.0450**	**0.8743**	**1.0225**	**0.9613**	**0.9701**	**0.8420**	11.4947	-0.0643
f_5	**0.8960**	0.7524	**0.9423**	**1.0170**	0.7029	**0.7693**	9.8250	0.3348
f_6	**0.9309**	0.7763	**0.8984**	**1.0055**	**0.8245**	0.6339	9.3709	0.7682

Based on the threshold value, factors f_1 and f_2 will affect factor f_4; factor f_3 will affect factors f_1, f_4, f_5, and f_6. Factor f_4 will affect all factors, while factor f_5 will affect all factors except f_2 and f_5. Factor f_6 will affect f_1, f_3, f_4, and f_5. Therefore, based on the above calculations, during the training, more attention should be paid to mobility, which affects all factors. Another important issue is to pay more attention to muscle strength, which appeared to be the most dominant factor.

The impact–relation map, which presents the causal relations between various factors of motor ability is presented in Figure 1. Elements located above the horizontal axis are the cause, while elements below the horizontal axis are the effect in the cause–effect chart.

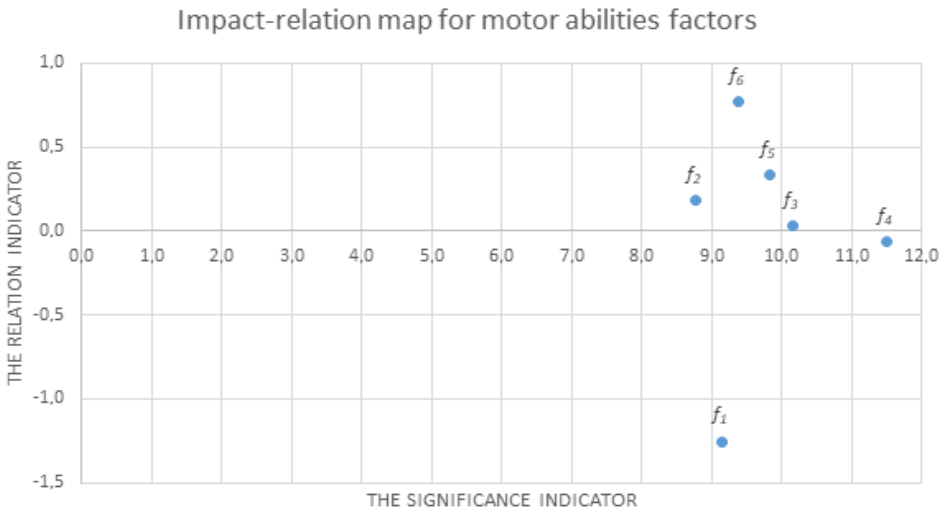

Fig. 1. The cause–effect relation diagram of the influence of various factors of motor ability on sailing performance.

Within the examined factors of motor abilities, two of them, namely: quickness and mobility, are considered as an effect. Quickness (f_1) with a result of -1.2532 is considered as the main effect of motor ability, compared to mobility with a result of -0.0643. The remaining factors are the cause, with significant differences within this group. Muscle strength (f_6) with a result of 0.7682 is the main cause, compared to flexibility (0.3348), endurance (0.1856), and motor coordination (0.0288). In the case of significance, the highest value is for mobility (11.4947), before motor coordination (10.1530), flexibility (9.8250), muscle strength (9.3709), quickness (9.1502), and endurance (8.7727). The importance of weights of factors of motor ability is presented in Table 5.

Table 5. Importance weights for factors of motor ability (equation 6).

Factor	Weight	Ranking
f_1	0.1557	5
f_2	0.1493	6
f_3	0.1728	2
f_4	0.1956	1
f_5	0.1672	3
f_6	0.1595	4

The elements of sailing performance are presented in Table 6.

Table 6. Factors of sailing performance.

Factor	Sailing performance factors
f_1	motor abilities
f_2	sailing technique
f_3	tactical knowledge
f_4	racing rules knowledge
f_5	equipment
f_6	muscle strength
f_7	meteorology knowledge

The results of the normalized direct-relations matrix **X** for sailing performance factors are shown in Table 7.

Table 7. Normalized direct-relation matrix **X** for sailing performance factors (equation 1).

	f_1	f_2	f_3	f_4	f_5	f_6	f_7
f_1	0	0.2868	0.1208	0	0.0302	0.1962	0
f_2	0.1509	0	0.2076	0.0755	0.1509	0.2264	0.0377
f_3	0.0604	0.0604	0	0.1660	0.0604	0.2264	0.1962
f_4	0	0.1208	0.2868	0	0.1358	0.1811	0.0302
f_5	0.0604	0.2113	0.1660	0.0453	0	0.1509	0.0755
f_6	0.166	0.2113	0.2717	0.1208	0.0906	0.0453	0.0943
f_7	0.0755	0.0453	0.2566	0.0453	0.1057	0.1057	0

The total impact matrix **T**, the significance indicator, and the relation indicator are presented in Table 8. The threshold value α is 0.5314; therefore, all values of factors which are greater than the threshold value are bolded.

Table 8. Total impact matrix **T**, significance indicator, and relation indicator (equation 3).

	f_1	f_2	f_3	f_4	f_5	f_6	f_7	D_i+C_i	D_i-C_i
f_1	0.3056	**0.6837**	**0.6990**	0.2820	0.3171	**0.7291**	0.2642	6.0265	0.5349
f_2	0.4921	**0.5501**	**0.9131**	0.4133	0.4789	**0.8803**	0.3693	8.3144	-0.1201
f_3	0.3742	**0.5351**	**0.6883**	0.4560	0.3782	**0.8025**	0.4695	9.5300	-2.1222
f_4	0.3264	**0.5837**	**0.9166**	0.3266	0.4413	**0.7830**	0.3491	6.3497	1.1038
f_5	**0.3677**	**0.6366**	**0.7760**	0.3388	0.3025	**0.7198**	0.3527	6.2464	0.7420
f_6	0.5511	0.7916	**1.0692**	0.5004	0.4829	**0.8246**	0.4634	10.0276	-0.6612

Based on the threshold value, factors f_1, f_2, f_3, f_4, and f_5 will affect factors f_2, f_3, f_6. Factor f_6 will affect factors f_1, f_2, f_3, and f_6. Factor f_7 will affect factors f_3, and f_6. The significance of mental fitness (f_6), tactical knowledge (f_3), and sailing technique (f_2) is the highest; therefore, during training, more attention should be paid to improving these factors.

The impact-relation map, which presents the causal relations between various factors of sailing performance is presented in Figure 2. Elements located above the horizontal axis are the cause, while elements below the horizontal axis are the effect in the cause–effect chart.

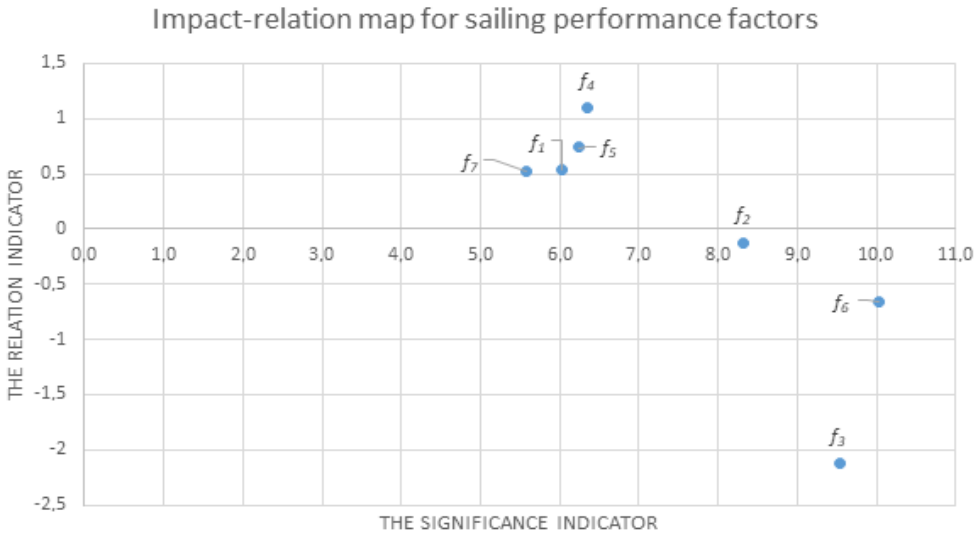

Fig. 2. The cause–effect relation diagram of various factors of sailing performance.

Within the examined factors of sailing performance, three of them, namely: sailing technique, tactical knowledge, and mental fitness, are considered as an effect. Tactical knowledge with a result of -2.1222 is considered as the main effect, compared to mental fitness (-0.6612) and sailing technique (-0.1201). Racing rules knowledge (f_4) with a result of 1.1038 is considered as the main cause; therefore, it is the most dominant factor, compared to equipment (f_5) (0.7420), motor abilities (f_1) (0.5349), and meteorology knowledge (f_7) (0.5229). In the case of significance, the highest value is for mental fitness (10.0276), before tactical knowledge (9.5300), sailing technique (8.3144), racing rules knowledge (6.3497), equipment (6.2464), motor abilities (6.0265), and meteorology knowledge (5.5777).

Based on the obtained results, the hypothesis concerning tactical knowledge as a dominant and most significant factor of sailing performance cannot be supported. Tactical knowledge is second in terms of significance following mental fitness. The most dominant factor is racing rules knowledge.

The importance of weights of factors of sailing performance is presented in Table 9.

Table 9. The importance of weights of factors of sailing performance (equation 6).

Factor	Weight	Ranking
f_1	0.1157	6
f_2	0.1597	3
f_3	0.1830	2
f_4	0.1219	4
f_5	0.1200	5
f_6	0.1926	1
f_7	0.1071	7

4. Discussion

The main purpose of this paper was to determine the effect of mutual relations between various motor abilities and factors of sailing performance on the sailing result in Olympic sailing classes. Therefore, it was essential to research the mutual causal relations between various factors of motor ability and sailing performance.

Physical fitness is crucial in sailing [9], and it depends on the yacht type and the position of the crew in the boat [16]. However, there are no previous studies concerning the mutual importance and relations between various factors of motor ability in sailing. Based on the conducted calculations (Table 4, Table 5, and Figure 1), it can be concluded that the most dominant factor, influencing others to the greatest extent (in the considered dataset) is muscle strength (f_6), and the factor which has the highest significance is mobility (f_4). Two factors received a negative value of the relation indicator; their impact is as an effect of other factors. The first is quickness (f_1), which received the highest negative value of the relation indicator, and mobility (f_4) is the other. Based on the above-mentioned calculations, it can be stated that mobility is the most important factor, although it can be perceived as an effect of other factors of motor abilities. On the other hand, muscle strength, which is fourth out of six factors in terms of significance, can be perceived as the main cause of other factors of motor abilities. Therefore, it can be stated that during the training of motor abilities the main focus should be on muscle strength [12, 16] and mobility. Even though endurance can be perceived as one of the key factors of physical preparation for sailing [15], due to the nature of Olympic sailing, other factors are more significant, which is in line with research performed for Laser dinghy sailors [14].

Based on the conducted calculations (Table 8, Table 9, and Figure 2), it can be concluded that mental fitness (f_6) is the most significant factor of sailing performance before tactical knowledge (f_3) and sailing technique (f_2); all factors are considered as an effect, with the highest negative value for tactical knowledge and mental fitness. Other factors of sailing performance are considered as a cause, with the highest relation value of 1.1038 for racing rules knowledge (f_4), before equipment (f_5). The other two factors, motor abilities (f_1) and meteorology knowledge (f_7), are considered as having almost equal relation indicators. Both factors are also considered as one of the least significant, although motor abilities have a higher value of significance indicator than meteorology knowledge. Mental fitness and other psychological skills are some of the key aspects of performance in professional sport [46]. Therefore, it is not surprising that this factor is the most significant based on this study. Tactical knowledge is considered as the most significant effect of sailing performance [14], although in terms of the importance of weights of factors of sailing performance, mental fitness is ranked first. The main reason for this situation can be the importance of decision-making processes during stressful situations [7, 14]. Even though Olympic sailing is a sport with great physical fitness demand [9, 12, 15, 16], compared to other factors of sailing performance, motor abilities belong to the least important factors.

The DEMATEL approach used in this study proved the significance of mental fitness and tactical knowledge. This research is the first one that proved the importance of racing rules knowledge in the context of sports results.

One of the main limitations of this study was the sample size. Therefore, this study was cross-sectional, and interpretation of the result should be made with caution. Due to a limited number of participants, the causality cannot be inferred. It would be interesting to have a larger sample of sailors in terms of the number and yacht type. Even though the DEMATEL method allows performing research on a limited group of experts [37, 38], it would be more interesting to extend this research to a larger sample, including all experienced sailors from Olympic classes, also from other countries – especially countries with a long sailing tradition, like Great Britain, Australia, and New Zealand. This could be the further research direction to compare the results obtained during this study with opinions from other expert sailors. Another further research direction is connected with expanding the research method through performing the quantitative measurement of motor abilities and comparing it to the obtained results of the impact–relation map.

5. Conclusions

This study confirmed the importance of mental fitness and tactical knowledge in sailing performance, even though the number of sailors participating in the study was limited. This paper is the first one that attempted to determine the mutual causal relation

between various factors of motor ability and sailing performance. This fills the research gap concerning the importance of various factors of sailing performance in the context of improvement in training methods.

In conclusion, the most important aspects influencing sailing performance are mental fitness and tactical knowledge. Therefore, to improve the training process of Olympic class sailors, there should be more focus on these two factors.

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