

Validity of testing and training using the kayak ergometer

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Abstract

Purpose: The paper is dedicated to the problem of the strength testing and training using the ergometer rowing performance in the flat water kayak sport. The aim of the research was to create a model of validity based on the relationship between the ergometer and on-water performance competition rowing.

Material: Nineteen 15–17 years old male kayak rowers during the off-season were randomly divided into two groups. An experimental group trained according the same program as the control group, but two times a week a part of the common strength training exercises was substituted with a high-intensity strength training using the ergometer rowing. A whole amount of strength loading on all the rowers of the two groups was equal. Validity of testing and training of the ergometer rowing in the kayak sport was evaluated using interclass correlation between competition performance on 500 m on-water kayak and ergometer rowing.

Results: Strong significant correlation is revealed between competition performance of on-water kayak and ergometer rowing before and after the off-season ($|r| = 0.892, 0.902, p < 0.001$), that shows rather good validity. Other result of the correlation analysis shows good prognostic ability of the ergometer performance regarding competition performance of on-water kayaking ($|r| = 0.913$).

Conclusions: The proposed model based on the relationship between the ergometer and on-water performance competition rowing shows rather good validity of the strength testing and training in the on-water kayak sport.

Keywords: flat-water kayaking, rowing, competition, performance, modelling.

Introduction

The kayak rowing is a strength-endurance type of sport and competition performance depends on factors such as aerobic and anaerobic power, physical power, rowing technique and tactics. Therefore, a rower has to develop several capacities in order to be successful and a valid testing battery of a rower has to include parameters that are highly related to rowing performance. Endurance training is the mainstay in rowing. For the 2000 m race, power training at high velocities should be preferred to resistance training at low velocities in order to train more specifically during the off-season. The specific training of the international rower has to be approximately 70% of the whole training time [1].

Rowing ergometers were designed with a purpose to simulate rowing indoor exercises. During the last several decades, rowing ergometers revolutionised the training and testing of kayak sportsmen [2]. The ergometers were primarily used to simulate biomechanical movements and physiological stresses associated with a specific force of kayak paddling. Several ergometers with different designs can be used by rowers as part of their indoor training [3].

The ergometers are used not only for training, but for testing of rowing techniques and mechanical efficiency of paddling, too. Michael et al. examined elite kayakers and identify a number of key biomechanical performance variables during maximal paddling on a custom kayak simulator. Results indicated a significantly greater mechanical efficiency during the right paddle stroke compared with the left ($p < 0.025$). In addition, analysing

the effect of period, peak paddle force demonstrated a significant reduction when comparing the beginning to the middle and end of the simulated race respectively ($p < 0.025$). Examination of individual force profiles revealed considerable individuality, with significant variation in the time course of force application [4].

Greene, et al. studied the effect of ergometer design on rowing stroke mechanics. No differences were found in the mechanical energy delivered to the handle of the three ergometers; however, greater joint mechanical energy production of the lower limb reduced mechanical efficiency when rowing using the fixed ergometer. The fixed foot stretcher on the fixed ergometer acts to increase the inertial forces that the rower must overcome at the catch, increasing the moment and power output at the knee, and affecting the coordination pattern during the recovery phase [5].

Fleming et al. assessed muscle recruitment patterns and stroke kinematics during ergometer and on-water rowing to validate the accuracy of rowing ergometry. Their results suggest that significant differences exist while comparing recruitment and kinematic patterns between on-water and ergometer rowing ($p < 0.01$). These differences may be due to altered acceleration and deceleration of moving masses on-ergometer not perfectly simulating the on-water scenario [6].

Sarabon et al. formulated a paradigm that to improve validity of testing and training of a rowing ergometer means to reduce the discrepancy between the rowing ergometer and on-water rowing. With this purpose they evaluated the effect of rowing ergometer compliance

on biomechanical and physiological indicators during simulated 2,000-metre race of young competitive rowers. The study compared biomechanical characteristics and physiological responses during rowing on three devices: stable ergometer, transversally compliant ergometer, and frontally compliant ergometer with stroke rate, average force, power output, velocity and amplitude of the handle and stretcher or seat, heart rate and blood lactate were measured at 500 m intervals. Force and power at the stretcher were significantly lower ($p < 0.03$) for transversally compliant ergometer, while stroke rate and velocities of the handle and the seat were higher ($p < 0.01$). No significant differences were observed between stable and frontally compliant ergometer in biomechanical parameters. The lowest rowing performance was observed in frontally compliant ergometer ($p = 0.007$), and was accompanied with the highest average heart rate ($p = 0.031$). In the transversally compliant ergometer, rowers modified their technique, but were able to maintain physiological strain and performance. In contrast, frontally compliant ergometer had no effect on rowing biomechanics, but decreased rowing performance and increased physiological strain [7].

Benson et al. undertook comparison of rowing stationary and dynamic ergometer. Differences were more pronounced in males than females; this dichotomy may be more due to dynamic ergometer familiarity than sex. When rowing at a constant power output, all rowers used higher stroke rates and lower stroke forces on the dynamic ergometer as compared to the stationary ergometer. Cardiopulmonary demand was higher for all rowers, as measured by heart rate, and efficiency was lower [8].

Cycle training is an important training modality of elite rowers. Cycling is the preferred alternative to on-water and ergometer rowing as it provides a reduction in compressive forces on the thoracic cage and upper extremities while still creating a local and central acclimation to endurance training. Lindenthaler et al. used rowing and cycle ergometry to determine differences in physiological responses during rowing in elite male sportsmen. It is hypothesised, however, that there will be differences in physiological characteristics between ergometer rowing and cycling due to the principle regarding the specificity of training that elite rowers undertake. Understanding these differences will ensure more accurate training prescription when cycling [9].

Rowers regularly undertake rowing training within 24 h of performing bouts of strength training; however, the effect of this practice has not been investigated. Gee TI et al. evaluated the impact of a bout of high-intensity strength training on 2,000 m rowing ergometer performance and rowing-specific maximal power. This bout of high-intensity strength training resulted in symptoms of muscle damage and decrements in rowing-specific maximal power, but this did not affect 2,000 m rowing ergometer performance in highly trained rowers [10].

In order to validate ergometer usage in laboratory testing of athletes, a quantitative assessment of task

specificity must be established. Literature validating task specificity of various ergometer designs, using cardio-respiratory or biomechanical variables such as kinematic and force data exist. The development of reliable, commercially available air-braked kayak ergometers has led to their usage in training and testing of elite flat-water kayakers. Investigations into the validity of on-ergometer versus on-water testing for metabolic and cardio-respiratory variables have concluded that while kayak ergometers accurately simulated physiological demands of short-term high-intensity kayaking, a biomechanical assessment was required to determine how accurately kayak ergometers simulated the on-water scenario. Significant differences exist while comparing recruitment and kinematic patterns between on-water and ergometer rowing. These differences may be due to altered acceleration and deceleration of moving masses on-ergometer not perfectly simulating the on-water scenario [11].

Lawton et al. reviewed strength testing and training of rowers and identified strength tests that were reliable and valid correlates (predictors) of ergometer rowing performance. They established strength, power, and muscular endurance exercises for weight room training, which are strong determinants of success in specific performance measures used to assess elite rowers ergometer rowing performance. The question is about the ergometer rowing performance validity. A reasonable answer was regarding further research to examine the on-water benefits associated with various strength training protocols, in the context of the training phase, weight division, experience and level of rower, if limitations to the reliability and precision of performance data can be controlled [12].

Validity of testing and training of the ergometer rowing in the kayak sport is studied basing on the relationships between anthropometric characteristics, metabolic and biomechanical parameters, strength variables and rowing ergometer and on-water performance time [13]. Although the competition performance on-water time should be a criterion of skills in the kayak sport, there has been little research interest in on-water time trials for assessing rowing performance [14].

Research hypothesis: validity of testing and training of the ergometer rowing could base on the prediction of interclass correlation between competition performance of on-water kayak and ergometer rowing.

Purpose: the aim of the research was to create a model of validity of the strength testing and training based on the relationship between the ergometer and on-water competition rowing.

Material and Methods

Participants

Nineteen 15–17 years old male kayak rowers were involved into the research (body mass: 74.7 ± 3.1 kg, body length: 176.7 ± 2.8 cm). All the participants were good healthy; they trained according to the program for sport schools on kayak rowing [15].

This study was approved in advance by Ethical Committee of Lviv State University of Physical Culture. Parents of each the young participant voluntarily provided written informed consent before participating. The procedures followed were in accordance with the ethical standards of the Ethical Committee on human experimentation.

Procedure

The research was done during the off-season from November to April. Participants were randomly divided into two groups. One of these groups (control) consisted nine rowers which trained according the curriculum [15]. A bout of strength training consisted pressing a rod lying on a back, pulling a rod lying on the breast, pulling and jerking of the weight, exercises on the bars, various multi-joint barbell exercises etc.

Another group (experimental) consisted ten rowers trained according the same program as the control group, but two times a week a part of the common strength training exercises was substituted with a high-intensity strength training using the ergometer rowing. A whole amount of strength loading of all the rowers of the two groups was equal.

A time of 500 m kayak competition on flat water rowing was measured just before the off-season beginning (to the end of October) and just after the off-season ending (at the early May). From the very beginning of the off-season and just before the off-season ending, a number of maximal intensity double strokes with the rowing ergometer were measured during one minute.

Statistical analysis

Variation of measurements was estimated with the coefficient of variation:

$$V = \frac{SD}{M} 100\% \quad (1)$$

where SD : standard deviation, M : arithmetic mean. When $V < 10\%$, variation is small, 10–20% – moderate, and $V > 20\%$ – great.

Relative changing of training and competitive results during the off-season was calculated with formula:

$$\delta_{A-B} = \frac{M_A - M_B}{M_B} 100\% \quad (2)$$

where M_A , M_B are arithmetic means of groups' results after and before the off-season.

Relative difference of competitive results between the experimental and control groups was calculated with formula:

$$\delta_{E-C} = \frac{|M_E - M_C|}{M_E + M_C} 200\% \quad (3)$$

where M_E , M_C are arithmetic means of groups' results after and before of the off-season.

Validity of testing and training of the ergometer rowing in the kayak sport was studied in the frames of concurrent validity that refers to a measurement device's or method's ability to vary directly with a measure of the same construct. It allows showing that test is valid by comparing it with an already valid test [16].

The competition performance time was recognised as

valid because in kayaking sport like any other sport the competition performance is an imperative matter. Validity of testing and training of the ergometer rowing in the kayak sport was evaluated using interclass correlation between competition performance of on-water kayak and ergometer rowing.

Shapiro – Wilk test was used to evaluate probability of a normal distribution of results showed by the research groups. The results were elaborated using parametric statistics of centre and variation.

Fisher – Snedecor F-test was used to determine significance of differences in variations between the experimental and control groups. Student t-test for paired samples was used to determine significance of changing in rowing results during the off-season. Student t-test for independent samples was used to determine significance of differences between mean values of the experimental and control groups.

Validity of testing and training on the ergometer rowing in the kayak sport was evaluated using Pearson paired correlation between on-water kayak and ergometer performance rowing. Significance of the correlation was estimated with Student t-test for interclass correlation using the formula as follows:

$$t = |r| \sqrt{\frac{n-2}{1-r^2}} \quad (4)$$

where r is coefficient of correlation, n – number of participants in a group.

The computer package Statistica was used in data processing.

Results

Because near normal distribution ($SW-W = 0.899-0.951$, $p = 0.215-0.695$), parametric statistics were used to elaborate results of competitions and training (Table 1). During the off-season, both groups increased competition results in rowing ($p < 0.001$), but the experimental group showed significantly greater decrease of rowing time (3.3 s, 2.6%) than the control group: (1.9 s, 1.6%). Much more great increase was noticed in a number of double strokes with the rowing ergometer (11.2, 36.6%). Significance of the noticed increase in all the results is confirmed with paired correlation of the beginning and ending results ($r = 0.939-0.996$, $t < 0.001$).

Before the beginning of the off-season, experimental and control groups showed practically equal results in the water rowing competition: $p = 0.922$ (Table 2), but after the end of the off-season the experimental group convincingly surpassed the control group ($p = 0.160$). Groups variations of results in water rowing competition and ergometer rowing were rather small ($V < 10\%$), but variations of water rowing competition were times smaller ($V < 2\%$), than ergometer rowing ($V = 6.7, 7.9\%$).

Rather strong significant correlation was revealed between competition performance of on-water kayak and ergometer rowing before ($r = -0.892$, $p < 0.001$) and after the off-season: $r = -0.902$ (Table 3). Other result of the correlation analysis showed really good prognostic ability of the ergometer performance regarding competition

Table 1. Bias of results during the off-season

Group	EG (kayak)		CG (kayak)		EG (ergometer)	
	Before	After	Before	After	Before	After
Competition						
n	10		9		10	
<i>M</i> (s)	122.2	118.9	122.3	120.4	30.6	41.8
<i>SD</i> (s)	2.4	2.1	2.2	2.0	2.4	2.8
<i>Max</i> (s)	125.0	121.5	125.1	123.0	35.0	46.0
<i>Min</i> (s)	117.9	115.0	119.0	117.3	28.0	38.0
<i>V</i> (%)	2.0	1.8	1.8	1.7	7.9	6.7
<i>SW-W</i>	0.899	0.933	0.942	0.951	0.903	0.928
<i>p</i>	0.215	0.482	0.606	0.695	0.236	0.426
D_{A-B} (s/times)	-3.3		-1.9		11.2	
d_{A-B} (%)	-2.6		-1.6		36.6	
<i>t</i> *	11.9		21.9		44.9	
$t_{0.001, n-1}$	4.8		5.0		4.8	
<i>r</i> *	0.939		0.996		0.964	

Note: *n* – number of rowers; *M* – arithmetic mean; *SD* – standard deviation; *Max* – maximal; *Min* – minimal; *V* – coefficient of variance; *SW-W* – Shapiro–Wilk parameter; *p* – significance; Δ – difference between ending and beginning results at the off-season; *t* – Student statistics; *r* – correlation coefficient; * $p < 0.001$.

Table 2. Comparison of groups' on-water competition performance time regarding off-season

Competition Group	Before		After	
	Experimental	Control	Experimental	Control
n	10	9	10	9
<i>M</i> (s)	122.2	122.3	118.9	120.4
<i>MS</i> (s ²)	6.0	4.9	4.6	4.1
Δ (s)	-0.1		-1.5	
d_{E-C} (%)	-0.1		-1.2	
<i>F</i>	1.228		1.119	
<i>p</i> (<i>F</i>)	0.391		0.443	
<i>t</i>	0.099		1.470	
<i>p</i> (<i>t</i>)	0.922		0.160	

Note: *n* – number of rowers; *M* – arithmetic mean; *MS* – variance; Δ_{E-C} – difference between groups; *F* – Fisher–Snedecor statistics; *t* – Student statistics; *p*(*t*), *p*(*F*) – significance regarding mean values and variances correspondingly.

performance of on-water kayaking ($r = -0.913$).

These correlations have negative direction ($r < 0$), because in average decreasing of the on-water competition performance time was accompanied with increasing of a number of double strokes in the ergometer performance (Figure 1). Of course, correlations between one-named results before and after off-season have positive direction ($r > 0$), namely for the on-water competition performance

time it was 0.939 ($p < 0.001$) and for the number of double strokes in the ergometer performance – 0.964. These two coefficients confirm results of statistical hypothesis regarding changing of results of the on-water competition performance time and of the number of double strokes in the ergometer performance during the off-season. The same hypothesis regarding the control group showed a similar result: $r = -0.996$, $p < 0.001$ (see Table 1).

Discussion

The aim of the research was to create a model of validity of testing and training based on the relationship between the ergometer and on-water performance competition rowing. The model of validity derived in the research could be useful to validate investigations on relationships between results of tests and exercises and ergometer rowing performance.

Rowing races require developing high level of force and power output at high contraction velocity. Giroux et al. determined the force-velocity and power-velocity profiles of lower and upper limbs of adolescent rowers and their relationships with a 1,500-m rowing ergometer performance. The power developed during the 1,500-m (P_{1500}) was evaluated in fourteen national-level male rowers 15.3 ± 0.6 years old. The profiles were assessed during bench pull and squat jump exercises [17].

Maciejewski et al. investigate whether three different approaches for evaluating squat jump performance were correlated to rowing ergometer performance in elite adolescent rowers, who performed a 1,500-m all-out rowing ergometer performance and a squat jump test. The performance in the test was determined by calculating the jump height, a jump index, and the mean power output [18, 19]. According to the model created one could use analysis of correlation between ergometer and on-water rowing competition performances with a purpose to evaluate validity of these tests.

The same recommendation regarding validity of

the ergometer rowing performance could be directed to examination of the anthropometric and metabolic determinants of performance during 6,000-m of rowing on an ergometer and prediction of the 1000m rowing ergometer performance in young rowers [20].

The ergometer rowing during one minute was directed to strength training that is in harmony with recommendations by Lawton et al. While strength partially explained variances in 2000-m ergometer performance, concurrent endurance training may be counterproductive to strength development over the shorter term. Therefore, prioritization of strength training within the sequence of training units should be considered, particularly over the non-competition phase. Maximal strength was sustained when infrequent (e.g. one or two sessions a week) but intense (e.g. 73-79% of maximum) strength training units were scheduled; however, it was unclear whether training adaptations should emphasize maximal strength, endurance or power in order to enhance performance during the competition phase [21, 22].

The use of the ergometer rowing showed some training effect. With the same whole amount of the strength loading as in the control group, the experimental group using the ergometer rowers during off-season showed better on-water competition performance on the 500 m distance: 1.5 s, $p = 0.160$ (see Table 2).

Garcia-Pallares and Izquierdo investigated strategies to optimize concurrent training of strength and aerobic fitness for rowing and canoeing and recommend

Table 3. Correlation between of on-water kayaking and ergometer rowing performance regarding off-season

Measurements		Ergometer		Kayak	
		Before	After	Before	After
Ergometer	Before	-	10.21 ^o	5.59 ^o	6.35 ^o
	After	0.964*	-	6.14 ^o	5.91 ^o
Kayak	Before	-0.892*	-0.908*	-	7.70 ^o
	After	-0.913*	-0.902*	0.939*	-

Note: * r – coefficient of correlation; ^o t – Student statistics; $p < 0.001$.

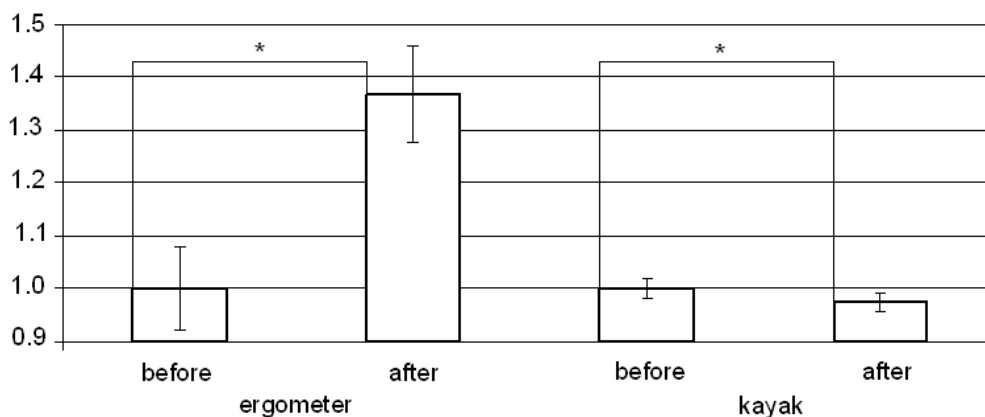


Figure 1. Relative results of the experiment group about the off-season ($M \pm SD$), * $p < 0.001$.

strategies, based on research, to avoid or minimize any interference effect when training to optimize performance in these endurance sports [23]. The created model of validity based on the strength preparation of kayak rowers performed competition on the short distances (200, 500 m). Analogical models could be created for the endurance preparation regarding long competition distances.

The model of the ergometer performance validity was derived on the male rowers results. There are no clear restrictions to disseminate this model on the female sport kayaking, but it should be a problem of a special research [24].

Conclusions

A problem of the ergometer performance rowing validity should be considered taking into attention the

ultimate aim of rowing sports – on-water competition performance time. The coefficient of correlation between the ergometer and on-water competition performance time is a quantitative measure of this validity. The model could be used as rather good prognostic instrument that was shown on the example of young kayak rowers during the off-season ($|r| = 0.913$, $p < 0.001$). The ergometer rowing has some training effect on the 500 m distance ($p = 0.160$).

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Conflict of Interest

The authors declare that there is no conflict of interest regarding this research.

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