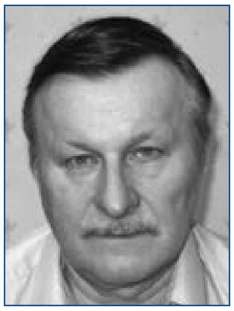
Paddling machine for kayaking sport: biomechanical tests and benefit analysis

UDC 796.012



Dr.Biol. **A.V. Voronov**[1]
Dr.Hab., Professor **P.V. Kvashuk**[1]
R.V. Malkin[1]
N.B. Kotelevskaya[2]
[1]Federal Scientific Center for Physical Culture and Sports, Moscow
[2]Saint Petersburg Research Institute of Physical Culture, Saint Petersburg

Corresponding author: Fizkult@teoriya.ru

Abstract

Objective of the study was to find to most beneficial individual paddling machine settings for the special strength training.

Methods and structure of the study. We used the G.M. Efremov Paddling Machine with a sliding seat and varied counterweights simulating the water resistance [3]; with the muscle electromyographic (EMG) activity fixed by a computerized Sportlab Test System (made in Russia) that includes an eight-channel telemetric electromyography, video camera, synchronizer and accelerometer [1]. We profiled the 1000Hz skin EMG of the following right-side muscles: m. triceps brachii_R, m. latissimus dorsi_R, m. vastus lateralis_R and m. gastrocnemius medialis_R. The EMG curves were inverted and smoothed by a moving average with a 50ms window; with the test process videos shot at 25 frames per second. We sampled for the tests 3 elite (Candidate Masters and Masters of Sport) kayakers.

The paddling machine test pace and resistant counterweight were varied in the ranges of 42 to 130 paddles/ min and 5 to 14 kg respectively.

The paddling cycle efficiency was rated by the EMG amplitude versus the competitive performance benchmarks.

Results and conclusion. Traditional strength trainings with squats with a barbell, bench presses etc. have proved ineffective or even harmful for the kayaking sports due to differences in the movement biomechanics. The Efremov Paddling Machine offers customizable strength training modes for the key paddling muscle groups, with the workouts managed so as to keep the average EMG amplitudes in the paddling machine workouts as close as possible to the actual water kayaking ones, otherwise arbitrary paddling machine settings may distort the individual competitive water kayaking stereotypes. As demonstrated by our study, the paddling pace and water resistance simulating counterweights of the paddling machine should be customized to the individual physical and technical fitness using the test data and analyses generated by modern biomechanical test systems.

Keywords: *kayaking techniques, paddling machine, biomechanics, EMG, benefit analysis, special strength, paddling cycle, paddling pace, water kayaking.*

Background. Since the rowing and paddling sports have always been seasonal, athletes have to widely use training machines in midseason times [4-6]. Modern paddling machines make it possible to closely mimic the actual competitive water kayaking techniques by customized workloads on the upper / lower limb and trunk muscles. Muscle-group-specific strength trainings need to be customized for the water resistance and paddling pace. The modern paddling machine settings may be individualized by varying the paddling pace and weight so as to keep the optimal strength training profile.

Objective of the study was to find to most beneficial individual paddling machine settings for the special strength training.

Methods and structure of the study. We used the G.M. Efremov Paddling Machine with a sliding seat and varied counterweights simulating the water resistance [3]; with the muscle electromyographic (EMG) activity fixed by a computerized Sportlab Test System (made in Russia) that includes an eight-channel telemetric electromyography, video camera, synchronizer and accelerometer [1]. We profiled the 1000Hz skin EMG of the following right-side muscles: m. triceps brachii_R, m. latissimus dorsi_R, m. vastus lateralis_R and m. gastrocnemius medialis_R. The EMG curves were inverted and smoothed by a moving average with a 50ms window; with the test process videos shot at 25 frames per second. We sampled for the tests 3 elite (Candidate Masters and Masters of Sport) kayakers.

The paddling machine test pace and resistant counterweight were varied in the ranges of 42 to 130 paddles/ min and 5 to 14 kg respectively. The paddling pace variations were computed using the formula:

$$\Delta Темп_i = \left(\frac{Темп_i - Темп_0}{Temp_0}\right) * 100\% \quad (1)$$

$\Delta Темп_i$ pace increment as % to the minimal; $\Delta Темп_i$ paddling pace; and $\Delta Темп_0$ minimal individual paddling pace. For example, when the pace grows from 66 to 132 p/ min, the pace increment ($\Delta Темп_i$) is 100%. We rated the muscle mioelectric activity to the paddle time to find the average EMG amplitude ($СрЭМГ_i^K$) of every paddling cycle as follows:

$$СрЭМГ_i^K = \frac{\left(\sum_{j=1}^{N} \frac{\int_{t=0}^{t=T_j} СглЭМГ_i^{j,K} dt}{T_j}\right)}{N} \quad (2)$$

$СглЭМГ_i^{j,K}$ smoothed paddling cycle EMG amplitude, mkV; i – muscle; K – kayaking; j – paddling cycle; N – number of paddles; T_j – paddle time, s; N – number of paddling cycle.

The paddling cycle efficiency was rated by the EMG amplitude versus the competitive performance benchmarks, i.e. matched with the $СрЭМГ_i^K$ paddling cycle amplitudes in the paddling machine tests with the water (competitive) kayaking ones (see Figures 1, 2); with the actual competitive EMG curves of an elite MS used as benchmarks. An individual minimal pace was fixed on the abscissa axis; and the average EMG amplitude (HZ) calculated by formula 2 fixed on the ordinate axis.

Results and discussion. The paddling machine workout efficiency is considered the highest when the muscle EMG amplitudes match with those for the competitive kayaking. For example, athlete V (with the individual paddling minimum of 65 paddles/ min) who tackled the special strength training of m. triceps brachii_R on the paddling machine, the machine was set at 86-96 paddles/ min (that means about 50% increment to the minimal pace) and the weight at 10-plus kg (Fig. 1 upper). Such paddling machine workout was tested to secure the m. triceps brachii_R average EMG amplitude in the paddling cycle almost the same as for the actual water kayaking.

When the paddling machine pace grows to 133 p/ m (104% increment to the minimum) and the paddling machine weight grows to 12kg, the EMG amplitude of the elbow extensor was tested to grow 2.5 times, with

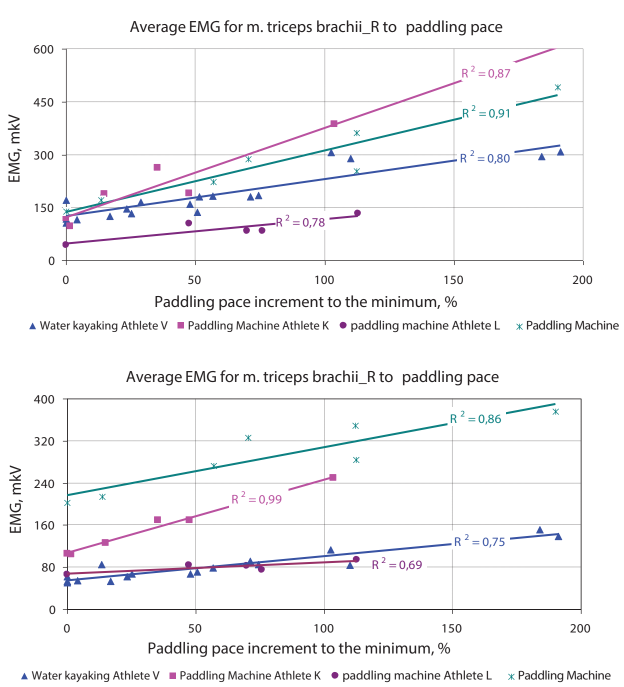


Figure 1. *Right-side limb/ trunk muscles EMG versus paddling pace for paddling machine and water kayaking*

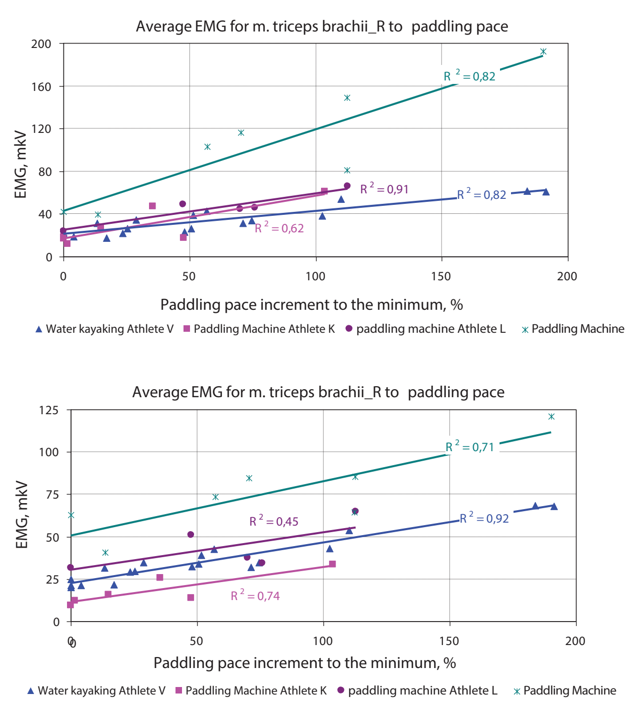


Figure 2. *Right lower limb muscles EMG versus paddling pace for paddling machine and water kayaking*

the workout getting unfocused i.e. the special strength transformed to hard strength training detrimental for paddling motor stereotype. Thus Athlete V in the paddling machine training was tested with excessive strain of m. latissimus dorsi _R.

Furthermore, the high-pace paddling machine workout (100-120 paddles /min, with 100% increment to the minimum) was tested to increase the EMG amplitude three times versus the water kayaking – with a meaningful change in the muscular effort profile. When the paddling pace was relatively low at 75 p/ min (increment of 15% to the minimum) with the weight of 8kg (Fig. 1, bottom), the m. latissimus dorsi_R performance profile (athlete V) was tested close to the water kayaking profile. However, the low-pace workout often fails to closely mimic the actual competitive motor stereotype.

In case of athlete L (with the paddling pace minimum of 43 p/ min), the paddling machine paddling pace of 90 p/ min (with 10-14 kg weight) and water kayaking training was found to increase the m. triceps brachii_R EMG amplitude to 250-360 mkV (Fig. 1 upper). This paddling pace appears to be a threshold in transition from the rational m. triceps brachii_R workout to an overstress. We recommended for athlete L the relatively low-pace (75-80 p/ min, with up to 86% increment to the minimum) workout with 10-minus kg weights as the most beneficial paddling machine workout scenario. The athlete L's paddling machine technique was tested with an excessive contribution of the widest dorsal muscle in contrast to the optimal water kayaking technique (Fig. 1 lower). For m. latissimus dorsi special strength training, therefore,, athlete L is not recommended to use such paddling machine settings.

In case of women athlete K (paddling pace minimum of 48 p/ min), the paddling machine pace was found matching with the competitive water kayaking profile, unless the excessive 8-14kg weights are applied – since they were tested to activate Golgi complexes in the muscle tendon [6]. As a result, the m. triceps brachii_R EMG amplitude was tested twice as little as that in the water kayaking workout (Fig. 1 upper). To maintain the paddling pace, athlete K has to add the m. latissimus dorsi_R efforts (Fig. 1 lower).

The paddling machine and water kayaking lower-limb muscle EMG profiles of athletes V and K were found to match (Fig. 2). Athlete L in the paddling machine with 72-120 p/ min pace (70-180% increment to the minimum) was tested with the m. vastus lateralis_R and m. gastrocnemius medialis_R EMG amplitudes significantly different from the water kayaking ones (Fig. 2). This was the reason for us to recommend him the paddling machine special strength trainings with 6-minus kg counterweights being kept within the relatively low paddling pace range. It is not unlikely that athlete L was still adapting to the paddling machine workouts in the test time.

Conclusion. Traditional strength trainings with squats with a barbell, bench presses etc. have proved ineffective or even harmful for the kayaking sports due to differences in the movement biomechanics. The Efremov Paddling Machine offers customizable strength training modes for the key paddling muscle groups, with the workouts managed so as to keep the average EMG amplitudes in the paddling machine workouts as close as possible to the actual water kayaking ones, otherwise arbitrary paddling machine settings may distort the individual competitive water kayaking stereotypes. As demonstrated by our study, the paddling pace and water resistance simulating counterweights of the paddling machine should be customized to the individual physical and technical fitness using the test data and analyses generated by modern biomechanical test systems.

References

1. Voronova A.A., Voronov A.V., Kvashuk P.V. Electromyographic methods to determine muscle groups to affect sports results in speed climbing. Teoriya i praktika fiz. kultury. No. 8. 2019. pp. 24-26.
2. Voronov A.V. Measuring devices with feedback: application in speed-strength training of skaters. Moscow: Sotsialno-politicheskaya mysl publ., 2010. 110 p.
3. Efremov G.M. Recommendations for the use of G. Efremov's simulator for training of elite athletes. Mir grebli. 2007. September. pp. 17-21.
4. Verlin S.V., Kaverin V.F., Kvashuk P.V., Semaeva G.N. Theory and methodology of kayaking and canoeing: analytical review. Voronezh: Tsentralno-chernozemnoe knizhnoe izdatelstvo publ., 2007. 173 p.
5. Fleming N, Done B., Mahony N. Electromiographic and kinesiological analysis of the Kayk Stroke: comparison of on-water and on-ergonomic data across exercise intensity. 12-th Annual Congress or the ECSS, 11-14 July 2007, Jyvaskale Finland.
6. Fleming N., Done B., Mahony N., Fletcher D. A biomechanical assessment of ergometer task specificity in elite flatwater kayakers. Journal of Sports Science and Medicine. 2012. Vol. 11. pp. 16-25.