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REPORT

Implementation of research on the impact of the TORQWAY vehicle on the human body

Executed in accordance with the contract dated 16.02.2015, as part of the project entitled "Conduct of the necessary research and work towards placing an innovative recreational and rehabilitation device called Torqway on the market"

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List of acronyms used

BH – body height

BM – body mass

BMI - body mass index

%F - the percentage of body fat

HR- heart rate

VE - lungs minute ventilation

VO₂ - minute oxygen uptake

VCO₂ - minute expulsion of carbon dioxide

RPE - a subjective sense of exertion difficulty, measured on a Borg scale (6 to 20 points)

%Vo_{2max} - the exertion intensity, expressed as a % of maximal minute oxygen uptake

%HRmax - the exertion intensity, expressed as a % of maximum heart rate

EE - energy expenditure

RER - respiratory factor

La - lactate concentration in the blood plasma

H^T - the concentration of hydrogen ions in the blood

p - the level of significance of differences

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1. Purpose of research

The purpose of completed research was to evaluate physiological and biochemical reactions of the human body while moving by means of the TORQWAY vehicle.

The specific objectives of the study were as follows:

- Comparing the repeatability of the physiological response to standard exercise performed on two TORQWAY vehicles;
- Estimate of the repeatability of the physiological response of the body to the standard exercise performed on the same TORQWAY vehicle (test-retest);
- Comparing the level of physiological and biochemical reactions and assessment of energy expenditure during exercise on TORQWAY and during the march, carried out at constant speed (4.8 km / h).

The research was carried out in full accordance with the methodology established in the offer.

2. Research methodology

Exertion testing was performed on two TORQWAY vehicles (labelled A and B) delivered for testing by Torqway Ltd. based in Toruń.

Each participant was informed of the purpose and course of study and gave written consent to participate in research. The study included:

- Medical examination allowing the exertion tests;
- Anthropometric measurements;
- Evaluation of aerobic efficiency of subjected men using the direct method (step test);
- Submaximal exertion, which rated the level of physiological and biochemical reactions in accordance with the objectives of research.

Prior to the stress testing research participants familiarized themselves with the technique of riding the TORQWAY vehicle. In order to master the art of precision of movement by TORQWAY, two sessions lasting approximately 30 minutes were scheduled. During the first training session the subjects learned to navigate on the device on a flat surface outside the laboratory, whereas during the second session they also acquainted themselves with the technique of moving on TORQWAY on the treadmill in the laboratory (about 15 minutes).

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During all the stress testing on both vehicles constant length of the arm (lever) was assumed, which was 90 cm.

2.1. Anthropometric measurements

The body height (BH) in male subjects was measured by a stadiometer (SEGA) with an accuracy of 1 mm. With body composition analyser, using bioelectrical impedance method (JAWON TOI 353), it was defined: body mass (BM), the percentage of body fat (%F), and body mass index (BMI).

2.2. Exertion testing

All the stress tests were carried out on a mechanical treadmill (h / p Cosmos, Saturn, Germany), with the angle of the substrate inclination of 0%.

During testing with ergospirometry (Cortex, Metalyzer 3B; Germany), minute oxygen consumption (VO_2) and minute lungs ventilation (VE) was measured, and the respiratory quotient (RER), was determined. Heart rate (HR) was measured with a heart rate monitor (Polar, S-61 Oi; Finland).

Biochemical analyses included determination of lactate concentration in the blood plasma (La) and the concentration of hydrogen ions (H^+) in the arterialized blood. Lactate concentration was determined by spectrophotometry (Spectrophotometer UV/Vis Evolution 201 Thermo Scientific), immediately after centrifugation of blood using an enzymatic test Lactate PAP by BioMérieux. Blood was collected into microtubes containing an anticoagulant and inhibitor of glycolysis. The concentration of H^+ ions was determined using an analyser RapidLab 348 Siemens.

Gradual test

The aim of the test was to measure the aerobic capacity of male respondents and the determination of maximum minute oxygen uptake (VC^{max}) as well as maximum heart rate (HR $_{\text{max}}$). The test began with a 4-minute warm-up performed with a running speed of 7,0 km/h. Then, every 2 minutes the running speed was increased by 1.2 km / h until subject's inability to continue (to extreme tiredness: the test carried out "until refusal" by the subject). The highest recorded magnitude of HR and VO_2 were considered maximum values.

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Stress test: comparison of physiological responses to a standard exercise performed on two TORQWAY vehicles

The aim of the test was to verify whether the body's physiological response is similar during physical workout on two different vehicles TORQWAY. The test was performed on a mechanical treadmill at a constant speed of 4.8 km / h. The test consisted of two exertions lasting 6 minutes each, with a 3 minute interval between exertions. During the first exertion test a subject performed exercise on the first device (randomly selected A or B). In between the exercises the device was exchanged and a second exercise (identical to the first one) was performed, this time on the second device. The level of physiological indicators recorded in the functional steady-state was analysed.

Stress test: a comparison of physiological responses to a standard exercise performed on the same TORQWAY vehicle (TEST-RETEST)

The aim of the test was to determine the repeatability of the physiological response of the body during operation on the same TORQWAY vehicle. The A vehicle was drawn for that test. The test was performed on a mechanical treadmill at a speed of 4.8 km / h and the exertion lasted 6 minutes. The study was carried out twice at an interval of one week. The level of physiological indicators recorded in the functional steady-state was analysed.

Exertion test: marching + exertion on TORQWAY

The aim of the test was to compare the physiological and biochemical responses of the body during marching and exertion on TORQWAY at a constant speed. In addition, the test determined the energy expenditure (EE) in both exertions. The test consisted of two exertions lasting 6 minutes each, with an interval of 3 minutes. Both exertions were performed at a speed of 4,8 km/h. During the first exertion a march was the type of movement, while the other the exertion was performed on TORQWAY (labelled B). The level of physiological indicators recorded in the functional steady-state was analysed. The energy expenditure was determined by indirect calorimetric in an open system (calculated from the oxygen consumption and respiratory rate RER). The intensity of exertion was expressed as % $\dot{V}O_2$ max and % HRmax. To evaluate the rate of perceived exertion (RPE) the Borg scale was used (scale from 6 to 20 points, where 6 = very, very light exertion; 20 = extremely hard exertion). Before the test, and immediately after each exertion (marching and working out on TORQWAY), a fingertip blood was collected for biochemical analysis.

3. Statistic analysis

For each indicator mean values and standard deviation was calculated. The level of significance of differences was determined using the non-parametric Wilcoxon test. The differences between the levels of indicators analysed were considered significant when $p < 0.05$.

4. Results

4.1. Characteristics of study participants

The study involved 11 healthy, untrained in competitive sports males aged 20.2 ± 1.3 years of age. Respondents were physically active (recreational physical activity). These were the persons with the correct body structure. The average level of somatic indicators developed among the participants as follows: body height 180.6 ± 5.4 cm, weight 73.3 ± 7.0 kg, the percentage of body fat $14.2 \pm 4.0\%$, body mass index 22.5 ± 2.1 . Maximum minute oxygen uptake in respondents was an average of 51.6 ± 3.5 mL / kg / min, while the maximum heart rate developed at an average of 198 ± 8.0 sk / min.

4.2. Comparison of physiological responses to the standard exercise performed on two TORQWAY vehicles

Tests carried out showed that the exercise performed on two different TORQWAY vehicles produces similar physiological response of the body: there were no statistically significant differences in the level of physiological indicators analysed in the men tested during exercise on a vehicle A and B (Table 1).

It should be noted that the exertion on the vehicle B was assessed by the respondents (subjective scale) as heavier than when working out on the vehicle A. Respondents indicated that (compared to the vehicle A) vehicle B is harder to control, more violently reacts to the turns, it requires more concentration and better technical skills than when riding on the a mechanical treadmill.

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Table 1. Comparison of physiological responses of the body during physical workout on two different TORQWAY vehicles

(Data are presented as an average \pm standard deviation)

Indicator	Vehicle A	Vehicle B	Significance of differences (p)
V_O₂ (L/min)	1.32\pm0.23	1.36\pm0.21	0.06
V_O₂ (mL/kg/min)	17.55\pm3.01	18.15\pm2.47	0.09
%V_O₂max	34.4\pm4.5	35.6\pm3.6	0.09
HR (sk/min)	131\pm16	131\pm14	0.82
%HRmax	66.0\pm8.4	65.8\pm8.0	0.82
RPE	9.5\pm1.5	10.4\pm2.8	0.18

4.3. Comparison of physiological responses to the standard exercise performed on the same TORQWAY vehicle (test-retest).

The results indicate that the effort performed within a few days on the same TORQWAY vehicle elicits a similar physiological response of the organism. The level of physiological parameters analysed in both tests (test-retest) was comparable (Table 2).

Table 2. Comparison of physiological responses of the organism during workout on the same TORQWAY vehicle

(Data are presented as an average \pm standard deviation)

Indicator	Test I	Test II	Significance of differences (p)
V_{O₂} (L/min)	1.32\pm0.23	1.28\pm0.26	0.72
V_{O₂} (mL/kg/min)	17.55\pm3.01	17.42\pm2.74	0.95
%V_{O₂}max	34.4\pm4.5	35.0\pm6.0	0.87
HR (sk/min)	131\pm16	129\pm15	0.1
%HRmax	66.0\pm8.4	65.1\pm7.3	0.3
RPE	9.5\pm1.5	10.3\pm2.5	0.20

4.4. Porównanie odpowiedzi fizjologicznej i biochemicznej organizmu podczas marszu i wysiłku na TORQWAY

The exertion on a TORQWAY vehicle, compared to a march performed at the same speed, is a workout more stressful to the organism. During the exertion on TORQWAY, a significantly higher level of analysed physiological indicators (pulmonary ventilation, heart rate, oxygen uptake) was noted than during a march. The intensity of exertion expressed as % V_{O₂}max was about 4-5% higher (34 vs. 29.4% V_{O₂}max) and by approximately 18% when the workout intensity was expressed as %HRmax (65 vs. 47%HRmax), than during a march. Energy expenditure was also significantly higher during exercise on TORQWAY than during the march and averaged on 384 kcal/h [6,5 kcal/min] (TORQWAY) and 320 kcal/h [5,3 kcal/min] (marching). With comparable pre-exertion values, after exercise on TORQWAY a higher concentration of lactate and hydrogen ions in the blood than was noted than in case of marching. In both tests, however, these values did not indicate any disorders of acid-base balance of the blood.

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Also, in the subjective assessment by persons subjected to the tests, an exertion on TORQWAY has been rated as heavier than marching (10.3 points vs. 7.5 points on a Borg scale). Detailed data is shown in Table 3.

The exertion on TORQWAY performed at a speed of 4.8 km/h can therefore be viewed as a workout of MODERATE intensity.

Table 3. Comparison of physiological responses of the body during marching (4.8 km/h) and exertion on TORQWAY (4.8 km/h)

(Data are presented as an average \pm standard deviation)

Indicator		March	TORQWAY	Significance of differences (p)
V _O ₂ (L/min)		1.10 \pm 0.17	1.28 \pm 0.26	0.003
V _O ₂ (mL/kg/min)		15.10 \pm 1.82	17.42 \pm 2.74	0.003
%V _O ₂ max		29.4 \pm 7.4	35.0 \pm 6.0	0.003
HR (sk/min)		94 \pm 15	129 \pm 15	0.003
%HRmax		47.2 \pm 7.4	65.1 \pm 7.3	0.003
VE (L/min)		24.6 \pm 3.9	35.0 \pm 7.2	0.003
EE (kcal/h)		318.8 \pm 53.4	384.5 \pm 90.9	0.003
EE (kcal/min)		5.3 \pm 0.9	6.4 \pm 1.5	0.003
RPE		7.5 \pm 1.7	10.3 \pm 2.5	0.003
La (mmol/L)	Before	1.62 \pm 0.77	1.69 \pm 0.79	0.66
	After	1.69 \pm 0.79	2.60 \pm 0.97	0.04
H ⁺ (nmol/L)	Before	38.72 \pm 2.21	39.03 \pm 2.07	0.53
	After	39.03 \pm 2.07	40.14 \pm 1.76	0.03

p<0.05 (statistically significant differences)

5. Final conclusions

The research allows the following conclusions:

- Physical exercise performed at the same speed on different TORQWAY vehicles, supplied

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by Torqway Ltd., elicited similar physiological response of the human body.

- The exertion on a TORQWAY vehicle was characterized by repeatability: the body's physiological responses in the TEST-RETEST study were similar.
- Compared to marching (4.8 km / h), the exertion on TORQWAY at the same speed proved a greater burden for the organism. The energy expenditure while exercising on TORQWAY is greater on average by about 65 kcal / h (about 20%) than during marching. The subjective feeling of severity of the exercise declared by the respondents was also greater when riding TORQWAY than during marching.
- The exertion on TORQWAY at a speed of 4.8 km / h can be evaluated as a workout of moderate intensity.

6. Concluding remarks

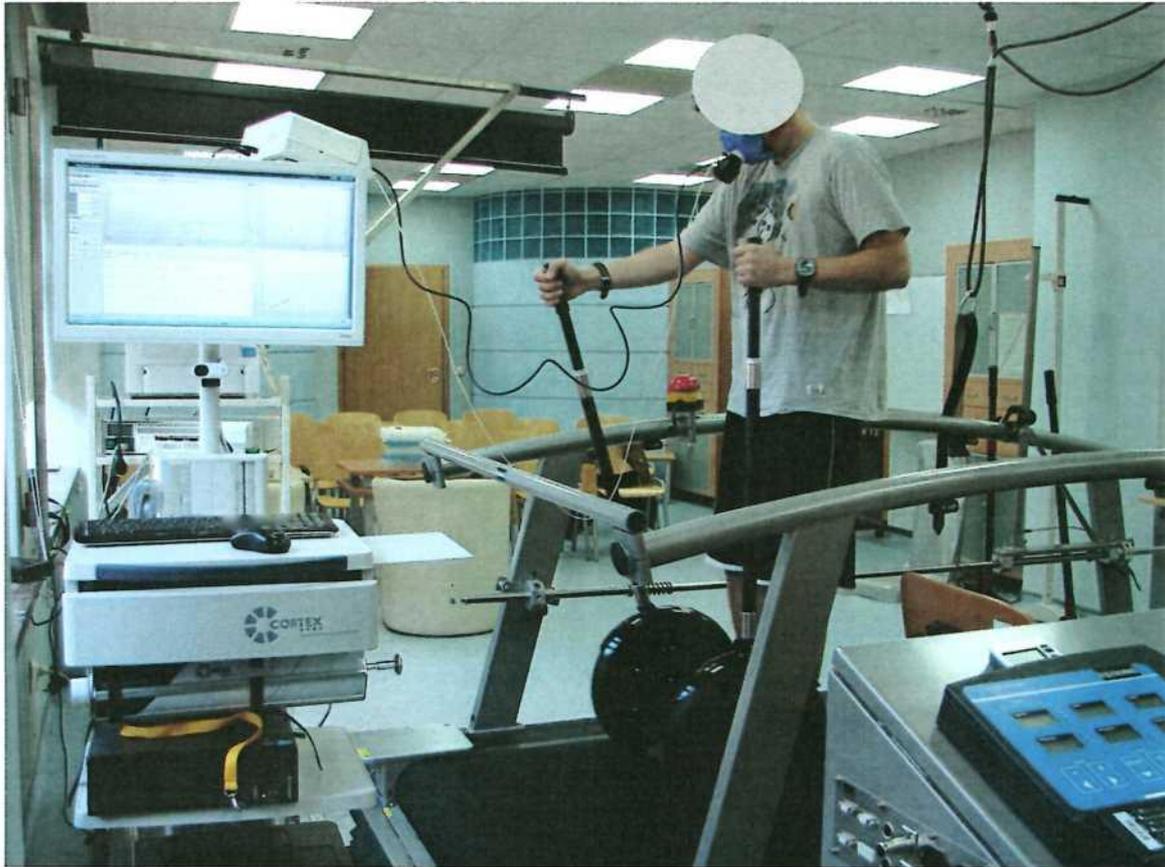
- In the future, it is possible to execute further physiological and biochemical study assessing for example: influence of the length of the arm (lever) on the severity of a workout; assessment of the impact of regular exercise on health of the organism with regard to the participation of people with different physical capacity and different body structure (e.g.: excess weight or obesity); or to determine the energetic cost in field conditions (beyond the laboratory).
- If the use of the TORQWAY vehicle for scientific research is planned, it is advisable to publish the results of this research in a reviewed scientific journal.

7. Appendixes

- Illustrative photos of selected respondents during testing (Photographs 1 i 2)

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- Classification of the severity of physical exertion, depending on the energetic cost for males (by Christensen) (Table 1)



Photograph 1. Laboratory exertion testing on TORQWAY



Photograph 2. A respondent during the exertion test.

Table I. Classification of the severity of physical exertion, depending on the energetic cost for males (by Christensen)

Severity of workout	Energy expenditure [EE] (kcal/min)
light	2.0-4.9
moderate	5.0-7.4
hard	7.5-9.9
very hard	10.0-12.4
extremely hard	over 12.5

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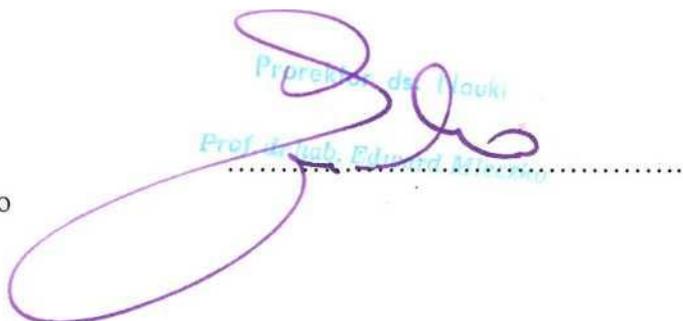
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