EFFECT OF VITAMIN D SUPPLEMENTATION ON THE LEVEL OF PHYSICAL FITNESS AND BLOOD PARAMETERS OF ROWERS DURING THE 8-WEEK HIGH INTENSITY TRAINING

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Abstract: The aim of the study is to reveal the effect of vitamin D_3 supplementation on physical capacity and blood parameters in rowers who apply high-intensity training. Vitamin D_3 supplementation can be a significant factor that supports training process and improves sports effectiveness in rowers who apply 8-week high-intensity training. Fourteen elite light weight rowers were divided into 2 groups. GS group was supplemented with vitamin D_3 (n=7), while GNS was placebo group (n=7). All participants completed the same training program during preparation period. A single-blind trial method was applied in D_3 vitamin rowers supplementation. All the experimental participants were informed on D_3 vitamin daily dosage i.e. 6000 IU per day. The results suggest that vitamin $D_{3,}$ whose concentration in blood increased by 400% in GS as a result of supplementation, could be the reason for the improvement of aerobic metabolism in the rowers and reduction of their inflammatory reactions in response to the high-intensity training.

Key words: rowers, aerobic capacity, training load.

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INTRODUCTION

Rowing requires from the sportsmen high aerobic and anaerobic capacity supported by effective technique skills adjusted to the environmental conditions (Ingham i wsp., 2002; Mikulić, 2008). Judging by the involvement of biochemical pathways in energy delivery for the activity, rowing is considered an endurance discipline. During 2 000m race 70% of energy requirements are covered by aerobic system and 30% by anaerobic system (Hagerman, 1984; Secher, 1993; Soma et al., 2010). The 2 000m race takes six to eight minutes (Hahn et al., 2000; Soma et al., 2010). During the first 500m anaerobic pathways dominate, then up to 1 800m oxidative reactions prevail, and during the last 200m anaerobic system is dominant again.

Considering rowers, the improvement in their endurance can be obtained by high-intensity interval training (Laursen et al., 2002). Such training comprises repeated sets of exercise, whose intensity is around or considerably above the maximal oxygen uptake of the rower, and breaks in between involving low-intensity activity or just passive recovery. This method is widely used during specific preparation period when training load consists of less volume but higher intensity practice then during general preparation period.

In 1922, McCollum discovered anti-rachitic compound in train oil. By airing and heating the substance he resolved the compound and the anti-rachitic factor was called Vitamin D. Further research revealed two natural compounds that differ in lateral chain structure:

- Vitamin D_2 (ergocalciol, ergocalciferol, calciferol) that occur in plants/yeast,
- Vitamin D_3 (calciol, cholecalciferol) that occur in animals.

D_2 and D_3 compounds that are considered vitamins, act in human bodies as prohormones. They are tricyclical alcohols of similar biological activity. Because of wider occurrence of vitamin D_3, it is more commonly used. Main role of this substance is to maintain homeostasis of calcium and phosphor in order to support mineralization of the skeleton. Moreover, it regulates growth and development of cells not only in kidneys, bones, parathyroid glands and intestines but also in other tissues. Furthermore, it controls the hormonal systems and influences immunity (Campbell & Allain, 2006).

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There is no consensus among scientists regarding the optimal level of $D_{3,}$ but 30ng/mL is considered safe (Hamilton, 2011). Low content of vitamin D_3 in products that are consumed and insufficient exposition to solar radiation in adults lead to osteomalacia – softening of bones (Hames & Hooper, 2009). Moreover, it can lead to muscles disorders (Zittermann, 2003). The studies revealed that vitamin D_3 supplementation causes the increase in muscular strength of lower extremities in older people regardless of physical activity. Cannel et al. (2009) in the survey article suggest that the sportsmen with vitamin D_3 deficiency should be supplemented with this vitamin in order to improve their sports performance. This suggestion is justified by the fact that the sportsmen achieve their best results in summer while exposition to the solar radiation. The authors suggest that the replenished level of 25 (OH) D_3 can protect the sportsmen against acute and chronic diseases. Similarly, Campbell and Allain (2006) revealed that muscular strength is highly related to vitamin D_3 deficiency and that this vitamin reduces the risk of bone brittleness and indirectly influences the work of muscles. However, these authors draw attention to the fact that it is very hard to prove these assumptions in scientific terms. Considering the above, it could be assumed that vitamin D_3 supplementation together with training load can induce adaptive changes of both aerobic and anaerobic metabolism in sportsmen of different disciplines.

OBJECTIVE

Because of insufficient exposition to the solar radiation during winter and early spring of Polish sportsmen that practice outdoor, the aim of the study is to reveal the effect of vitamin D_3 supplementation on physical capacity and blood parameters in rowers who apply high-intensity training.

HYPOTHESIS

Vitamin D_3 supplementation can be a significant factor that supports training process and improves sports effectiveness in rowers who apply 8-week high-intensity training.

MATERIAL AND METHODS

14 elite light weight rowers were divided into 2 groups. GS group was supplemented with vitamin D_3 (n=7), while GNS was placebo group (n=7). There were no significant differences between the groups in $VO_{2max,}$ height and body mass (table 1). The average training experience of the participants was 8 years. All participants completed the same training program during preparation period. None of the rowers took part in the regatta competition during training program. All subjects were fully informed of any risks before giving their written informed consent to participate in this experiment. The study was approved by the Ethical Committee of Regional Medical Chamber. The characteristics of the sample are presented in table 1.

The experiment started on Mondays' morning. The participants' blood was taken from the cubital vein. Blood cell count (WBC, RBC, HGB, HCT, MCV, MCH, MCHC, PLT, OB.), ASPAT, ALAT, GGTP, LDH, CK, total cholesterol, lipid profile (HDL, TGL, LDL), creatinine, phosphates, calcium salts, electrolytes (natrium, potassium, chloride) were determined by automatic analyser A-15, BIOSYSTEMS S.A, Costa Brava, Barcelona, (Spain, 2012). **V**itamin 25-OH-D content in blood was determined by analyser ARCHITECT-SYSTEM ABBOT brand, Wiesbaden (Germany, 2011) with the use of 3L52 ARCHITECT 25-OH Vitamin D Reagent Kit. TAS (total antioxidative status) in blood plasma was determined by the ready set of reagents Randox brand (TAS, Cat No. NX 2332, UK). Enzymatic method was applied to determine lactic acid concentration in blood with the use of set of reagents Randox brand. Extinction was registered at 37^0C by spectrophotometer EPOLL 200 type, Serw-med s.c. brand (Polska, 2006). Blood parameters were determined in accredited analytic laboratory by qualified staff.

All of the subjects performed a continuous graded exercise test on a rowing ergometer Concept II (model-C, Vermont, USA, 2009) with gas analyzer (Oxycon-Mobile, Erich JAEGER GmbH, Hoechberg, Germany, 2012) to determine the maximal oxygen uptake. The atmospheric conditions in the laboratory were: temperature of 20°C, 56% humidity, and atmospheric pressure of 991Hpa). The probe began with 3 minutes of rowing, with a load of 170 W. After this phase, the workload was systematically increased by 30 W every 3 minutes until exhaustion. The blood samples for lactate were taken from the fingertip after each 3 minute interval. The highest value of the oxygen uptake maintained for 15 s was considered to be the VO_2max (Hahn et al., 2000; Driller et al., 2009). Such indicators as HR, VO_2, VCO_2, RER, were obtained. The intensity where blood lactate concentration was 4 mmol/l was considered as lactate threshold (Ingham et al., 2002).

A single-blind trial method was applied in D_3 vitamin rowers supplementation. All the experimental participants were informed on D_3 vitamin daily dosage i.e. 6000 IU per day (10 drops). None of the experimental participants was aware of placebo administration. The supplemented group was provided with D_3 vitamin supplement Vigantol in original package. The placebo group was provided an original Vigantol package as well but containing a substituted substance of similar color and taste (sunflower oil).

Statistical analysis was performed using Statistica version 10. The normality of distributions was tasted using the Shapiro-Wilk test. The following parameters were calculated: arithmetic mean (x), standard deviation (±SD), the two-way analysis of variance (ANOVA) followed by post hoc Tukey test and index p for statistical significance. The level of significance was set when $p<0,05$. Correlation analysis were carried out using the Pearson test.

RESULTS

Table 1. Biometric and somatic parameters in the rowers before and after 8-week high-intensity training period.

	GS		GNS		Interaction	Effect size
	before	**after**	**before**	**after**		
Age [yrs]	23,71 ±3,71	23,84 3,76±	22,57 ±1,51	22,65 ±1,56	-	-
Body mass [kg]	72,7 ± 1,76	71,4 ± 1,95*	73,8 ± 1,10	72,3 ± 2,33*	time	0,46
Body height [cm]	183,57 ±4,57	183,57 ±4,57	184,43 ±3,64	184,43 ±3,64	-	-
Body Mass Index [kg/m^2]	21,5 ± 0,92	21,2 ± 1,10	21,7 ± 0,95	21,3 ± 1,02*	time	0,44
Basal Metabolic Rate [kcal]	7644,6 ± 176,96	7568,4 ± 158,79	7758,3 ± 107,02	7675,3 ± 156,36*	time	0,46
Tissue resistance [Ohm]	486,3 ± 48,34	489,9 ± 58,31	511,3 ± 58,92	511,6 ± 61,67	-	-
Body fat [%]	6,4 ± 0,97	9,2 ± 1,57*	8,4 ± 2,84	11,0 ± 1,14*	time	0,59
Fat mass [kg]	4,6 ± 0,71	6,6 ± 1,01*	6,2 ± 2,16	7,9 ± 0,97*	group time	0,38 0,54
Fat free mass [kg]	68,0 ± 1,72	64,7 ± 2,49*	67,6 ± 1,70	64,4 ± 2,15*	time	0,73
Total body water [kg]	43,2 ± 16,71	47,5 ± 2,04	49,5 ± 1,22	47,1 ± 1,54	-	-

*statistical significant differences at $p<0,05$ between the results before and after the experiment.

Table 1 shows biometric and somatic parameters of the light weight rowers, taken before and after the experiment, with the division into vitamin D_3 supplemented and non-supplemented subjects. Parameters of fatness of the rowers seem to be highly exceeding the required values. A significant increase in body fat in both groups was observed within the 8-week training period. The fact that training load was changed within this period could be the reason: low-intensity effort was substituted by high-intensity activity and therefore the recovery breaks were longer. The previous stage of preparation involved a low-intensity activity that engaged oxidative metabolism what could be the reason for a decrease in body fatness of the sportsmen. Such relation is in accordance with human physiology knowledge. The change of metabolism during the experimental period caused by the change of training load from low to high intensity, caused the increase in energy needs in the rowers, thus the changes in their diet (calorie intake), and as a reason the increase in body fat.

Training load

One mezocycle of specific preparation consisted of eight training microcycles that comprised 77 training sessions in total.

Table 2 shows the time of work allocated to different intensity zones according to Sozański (1999) during consecutive microcycles:

Zone 1. low intensity, HR (Heart Rate) 130 – 140 beats/min,
Zone 2. moderate intensity, HR (160-180 beats/min. [La] 2-3 mmol/l,
Zone 3. high intensity, HR (175-180 beats/min), [La] 4-6 mmol/l,
Zone 4. very high intensity, HR (180-190 beats/min), [La] 7-14 mmol/l.
Zone 5. supramaximal intensity HR (150-160 beats/min).
Zone 6. Anabolic exercise (strength).

Results from the table 2 show that the mean time of effective work during one training session was about 84 min for the rowers during 8-week training period. Percentage of high-intensity exercise was 16,2%, what can be considered satisfactory.

Table 2. Time of work allocated to different intensity zones in the light weight rowers during 8-week period of high-intensity training.

Period	Consecutive microcycles	Recovery break time	Intensity zones						Total	Number of training sessions
			I	II	III	IV	V	VI		
Mezocycle of specyfic preparation	I	02:08:00	12:20:00	01:30:00	00:30:00	00:00:00	00:34:00	00:00:00	**17:02:00**	**12**
	II	02:08:00	12:20:00	01:30:00	00:30:00	00:00:00	00:34:00	00:00:00	**17:02:00**	**12**
	III	01:30:00	09:55:00	01:28:00	00:36:00	00:02:00	00:27:00	00:00:00	**13:58:00**	**10**
	IV	01:35:00	09:30:00	00:00:00	01:14:00	00:00:00	00:00:00	00:00:00	**12:19:00**	**9**
	V	01:01:00	07:15:00	00:00:00	00:26:00	00:00:00	00:08:00	00:00:00	**08:50:00**	**8**
Mezocycle proceeding the race	VI	01:52:00	10:10:00	01:30:00	00:30:00	00:00:00	00:26:00	00:00:00	**14:28:00**	**10**
	VII	01:56:00	08:10:00	01:28:00	01:00:00	00:02:00	00:08:00	00:00:00	**12:44:00**	**9**
	VIII	01:20:00	09:50:00	00:00:00	00:20:00	00:23:00	00:00:00	00:00:00	**11:53:00**	**7**
Total		**13:30:00**	**79:30:00**	**07:26:00**	**05:06**	**00:55:00**	**02:17:00**	**00:00:00**	**108:16:00**	**77**

Aerobic capacity

Table 3-6 show aerobic capacity indexes of the rowers with division into vitamin D_3 supplemented group (GS) and non-supplemented group (GNS). Higher values of aerobic capacity indexes were observed in the GS group: Power $_{La\ 2\ mmol/l}$ (tab.3), $[La]_{max}$ and $[La]_{recovery}$ (tab.4), VO_{2max} (tab.5), $HR_{recovery}$, $HR_{4mmol/l,}$ HR_{max} (table 6). Differences between values of these indexes were statistically significant. The assumption of beneficial effect of 8-week high-intensity training on physical capacity of the rowers was proved by the relations between the results with reference to time in both groups.

Table 3. Power values (W) obtained during a continuous graded exercise test of the rowers GS and NGS groups before and after 8-week high-intensity training period.

	GS		GNS		Interaction	Effect size
	before	after	before	after		
Power $_{La\ 2\ mmol/l}$ [W]	215,8 ± 34,23	228,6 ± 35,63*	202,1 ± 43,44	208,8 ± 44,75	Time	0,46
Power $_{La\ 4\ mmol/l}$ [W]	299,3 ± 25,06	305,2 ± 28,42	298,8 ± 19,27	300,2 ± 18,34	-	-
Power $_{max}$ [W]	375,7 ± 32,07	392,9 ± 25,14	362,9 ± 23,60	372,1 ± 28,85	-	-

*statistical significant differences at p<0,05 between the results before and after the experiment.

Table 4. Lactic acid concentration in blood [La] in the rowers during the rest, continuous graded exercise test, and in 5th min of recovery in supplemented (GS) and non-supplemented (NSG) groups before and after the 8-week high-intensity training period.

	GS		GNS		Interaction	Effect size
	Before	After	Before	after		
La $_{rest}$ [mmol/l]	0,9 ± 0,41	0,8 ± 0,25	0,8 ± 0,21	0,8 ± 0,17	-	-
La $_{max}$ [mmol/l]	10,5 ± 1,83	12,0 ± 1,25*	9,3 ± 1,88	10,6 ± 1,33	Time	0,43
La $_{recovery}$ [mmol/l]	11,7 ± 1,12	10,8 ± 1,54*	10,4 ± 1,92	9,9 ± 1,47	Time	0,40

*statistical significant differences at p<0,05 between the results before and after the experiment.

Table 5. Oxygen consumption (VO_2) in the rowers during the rest, continuous graded exercise test, and in 5th min of recovery in supplemented (GS) and non-supplemented (NSG) groups before and after the 8-week high-intensity training period.

	GS		GNS		Interaction	Effect size
	Before	After	Before	after		
$VO_{2\ rest}$ [ml/kg/min]	9,5 ± 1,77	8,3 ± 1,89	8,0 ± 1,18	7,8 ± 1,52	-	-
$VO_{2\ La\ 2\ mmol/l}$ [ml/kg/min]	42,6 ± 8,20	42,7 ± 7,22	44,4 ± 5,78	43,3 ± 5,18	-	-
$VO_{2\ La\ 4\ mmol/l}$ [ml/kg/min]	53,4 ± 8,16	51,1 ± 5,04	52,3 ± 1,66	55,9 ± 6,64	-	-
VO_{2max} [ml/kg/min]	58,7 ± 10,16	67,4 ± 1,42*	58,1 ± 2,43	64,7 ± 6,70*	czas	0,77
$VO_{2\ recovery}$	9,6 ± 1,42	8,8 ± 0,94	9,6 ± 0,38	9,1 ± 0,98	-	-

*statistical significant differences at p<0,05 between the results before and after the experiment.

Table 6. Heart rate (HR) in the rowers during the rest, continuous graded exercise test, and in the 5th min of recovery in supplemented (GS) and non-supplemented (NSG) groups before and after the 8-week high-intensity training period.

	GS		GNS		Interaction	Effect size
	Before	After	Before	after		
HR $_{rest}$ [bpm]	75,1 ± 4,34	67,7 ± 5,68*	73,9 ± 6,09	70,7 ± 5,41	time	0,37
HR $_{La\ 2\ mmol/l}$ [bpm]	150,6 ± 16,97	146,8 ± 14,29	153,3 ± 6,81	148,9 ± 5,31	time	0,34
HR $_{La\ 4mmol/l}$ [bpm]	176,7 ± 9,48	172,3 ± 11,10*	176,3 ± 7,24	174,9 ± 5,49	time	0,30
HR $_{max}$ [bpm]	189,3 ± 8,38	195,3 ± 7,16*	187,7 ± 7,72	193,3 ± 4,15	time	0,42

HR $_{recovery}$	112,6 ± 14,03	109,1 ± 13,66	111,9 ± 9,48	107,4 ± 8,38	-	-

*statistical significant differences at p<0,05 between the results before and after the experiment.

High-intensity training, mostly in the form of interval, can significantly change the metabolism of a sportsman. During such training damages of muscles as well as some internal organs occur. As a result, the level of cytokines, regarded as inflammatory (IL-1b, IL-6) and anti-inflammatory (IL-10), as well as protein C-reactive (CRP) increase. The tested subjects revealed a significant increase in IL-1b in GNS group, and increase in CRP with reference to time and groups (table 7).

Table 7. The level of cytokins (IL-1B i IL-10) and C-reactive protein (CRP) in the rowers in supplemented (GS) and non-supplemented (NSG) groups before and after the 8-week high-intensity training period.

	GS		GNS		Interaction	Effect size
	Before	After	Before	After		
Interleukin IL-1b [pg/mL]	1,4 ± 2,22	4,1 ± 2,61	0,8 ± 0,51	5,1 ± 4,25*	czas	0,49
Interleukin IL-10 [pg/mL]	2,5 ± 2,23	1,8 ± 2,22	3,1 ± 3,17	2,6 ± 2,01	-	-
CRP [mg/l]	2,6 ± 0,50	2,0 ± 0,48*	2,3 ± 0,15	2,4 ± 0,27	czas grupa x czas	0,31 0,54

*statistical significant differences at p<0,05 between the results before and after the experiment.

The significant activity of liver enzymes AspAT (asparagine aminotransferase), GGTP (gamma-glutamyltransferase) and LDH (lactate dehydrogenase) suggests that the applied training program, after its completion, improved the function of some organs such as liver, heart or kidneys. The decrease in enzymes activity was greater in GS group. This group revealed also low, which was satisfactory, activity of creatine kinase (CK) – the damage indicator of skeletal muscles (table 8).

Table 8. The activity of some enzymes that are muscle damages indicators in the rowers in supplemented (GS) and non-supplemented (NSG) groups before and after the 8-week high-intensity training period.

	GS		GNS		Interaction	Effect size
	Before	After	Before	After		
ALAT [U/l]	19,6 ± 3,05	19,7 ± 3,25	20,4 ± 3,41	24,1 ± 6,52	-	-
AspAT [U/l]	29,3 ± 5,99	23,3 ± 6,05*	28,9 ± 4,14	24,7 ± 5,12*	time	0,83
GGTP [U/l]	19,4 ± 4,93	16,6 ± 4,47*	19,7 ± 2,06	16,9 ± 2,41*	time	0,68
Creatinine [mg/dl]	1,0 ± 0,04	0,9 ± 0,11	1,0 ± 0,04	1,0 ± 0,11	-	-
CK [U/l]	226,3 ± 130,66	229,0 ± 112,43	166,9 ± 40,45	182,9 ± 57,02	-	-
LDH [U/l]	370,6 ± 45,52	299,7 ± 42,77*	359,3 ± 11,60	326,0 ± 31,58*	time group x time	0,88 0,48

*statistical significant differences at p<0,05 between the results before and after the experiment.

Vitamin D_3 supplementation in group GS caused the increase of its concentration in the rowers by 400% (p<0,05). In NGS group an increase in vitamin D_3 concentration by 100% (p<0,05) was probably the effect of the exposition to solar radiation in April and May (fig. 1). No statistical significant differences were registered for total antioxidative status (TAS) in the rowers of both groups (figure 1; figure 2).

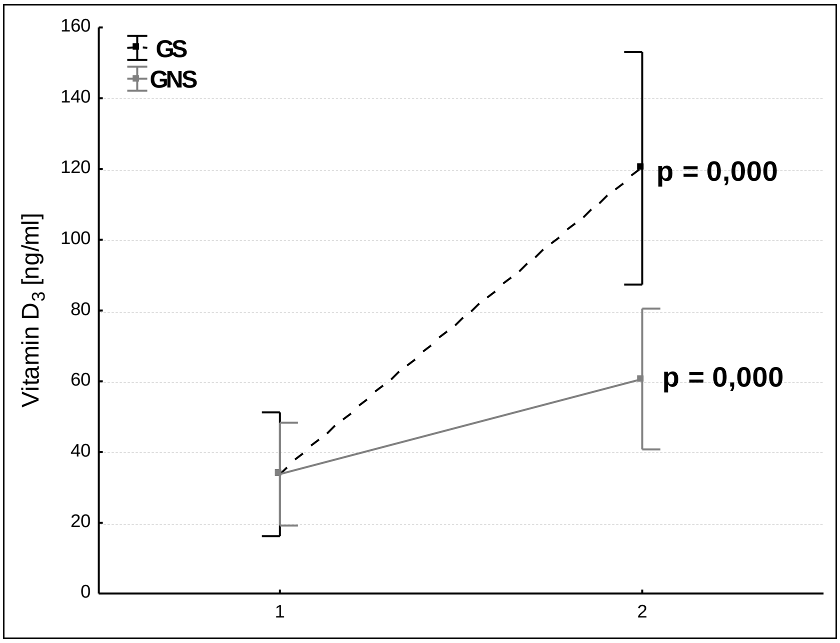

Figure 1. Vitamin D_3 concentration in blood in the wer before and after 8-week high-intensity training in vitamin supplemented (GS) and non supplemented (GNS) groups

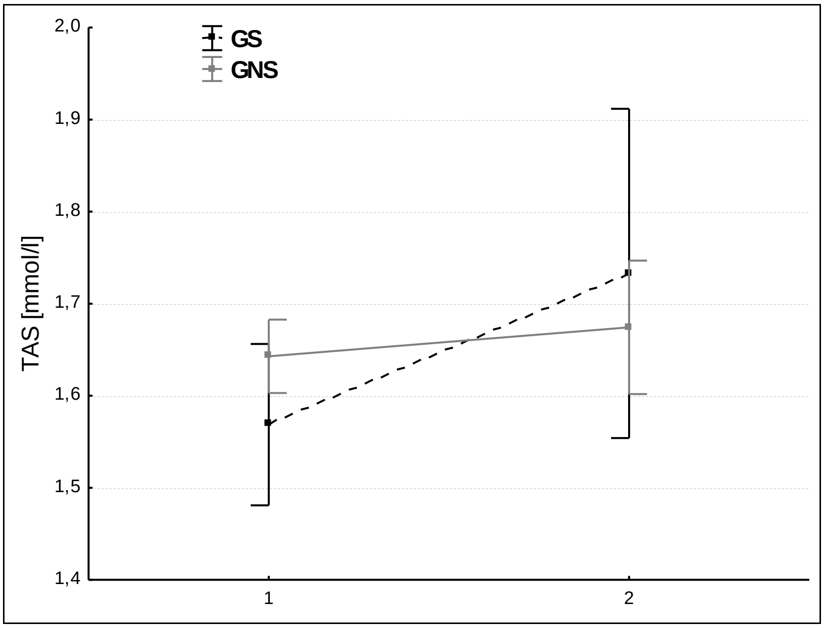

Figure 2. Antioxidative statuse (TAS) in the rowers before and after 8-week high-intensity training in vitamin supplemented (GS) and non-supplemented (GNS) groups.

DISCUSSION

Supplementation the rowers with vitamin D_3 during 8-week high-intensity training period considerably influenced the indexes of physical capacity and metabolic processes in many subjects. Significant higher results of power and oxygen consumption obtained during a continuous graded exercise test were observed in supplemented group. At the same time their blood parameters such as IL-1b, CRP, LDH reached lower values. The results suggest that vitamin $D_{3,}$ whose concentration in blood increased by 400% in GS as a result of supplementation, could be the reason for the improvement of aerobic metabolism in the rowers and reduction of their inflammatory reactions in response to the high-intensity training.

High-intensity training (HIT) is a highly effective method of training and can improve the physical capacity by 2 - 4% (Laursen, 2010). While there are numerous studies regarding physiological adaptation to regular endurance training, there are little research on physiological reaction to HIT in experienced rowers (Driller et al., 2009). According to Laursen (2010) the optimal training load consists of 75% of total training volume performed at low intensity and 10-15% at very high intensity. In our study, the rovers performed 70,2% of total training load at low intensity, and 16,3% at high intensity. The values are similar to the reference results of other authors. During the 2 000m race about 70% of work is supported by aerobic system and 30% by anaerobic (Secher, 1993; Soma et al., 2010), and only a fraction of a total rowing distance is performed at high intensity. Driller et al. (2009) studied the rowers who performed a 4-week high-intensity interval training. The improvement was observed in VO_{2max} and anaerobic threshold values. Moreover, it was the first study on elite rowers that revealed time improvement by 2% (8 sec) in a 2 000m race, after the application of 4-week HIT. Laursen et al. (2002) tested the effect of a 2-week HIT on 14 experienced cyclists. They found that maximal power and ventilatory threshold increased. Our study revealed that the rowers in SG improved VO_{2max} results by 12.1 %, and in GNS by 10,3 % after the 8-week high-intensity training. It means that HIT is an effective training method in terms of aerobic capacity improvement. However, vitamin D_3 in GS, whose concentration increased by 400%, was probably another factor that improved aerobic metabolism. Moreover, the supplementation had an effect on biochemical parameters of blood in SG, and significant differences were observed between the groups. The changes were found in the parameters that are important factors of fatigue in muscles (CK, LDH), organs (ALAT, AspAT, GGTP, Creatinine), systemic inflammatory processes (CRP, IL-1b, IL-10) and defence against free radicals (TAS). After the 8-week training, beneficial (in terms of adaptation to physical effort) changes of these parameters were observed in the supplemented subjects. Although there are limited studies on the effect of vitamin D_3 supplementation on the improvement of sports performance, the scientists of the subject underline the need of numerous further studies among sportsmen of various disciplines in order to prove these thesis (Campbell&Allain, 2006; Cannell&Hollis, 2008; Cannell et al., 2009; Hamilton, 2011).

CONCLUSIONS

1. Supplementation with vitamin D_3 during the 8-week high-intensity training period was a significant fctor improving physical capacity of the sportsmen.
2. The rowers showed lower concentration of such blood parameters as: IL-1b, CRP, LDH, what can suggest the beneficial effect of vitamin D_3 on the reduction of inflammatory reactions and damages of organs as a result of high-intensity training.

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