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A COMPARISON OF METHODS FOR CALCULATING LACTATE ANAEROBIC THRESHOLDS IN JUDO AND MIXED MARTIAL ARTS ATHLETES

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Abstract. *The study aimed to determine the differences between exercise intensities at the anaerobic threshold values (V_{AT}) calculated with methods of lactate curve analysis such as LT_{visual}, LT_{loglog}, $LT_{4.0}$, $LT_{\Delta 1}$, and $LT_{D\text{-}max}$, and to build regression equations that allow athletic training specialists to compare V_{AT} values obtained from LT_{visual}, LT_{loglog}, $LT_{\Delta 1}$, $LT_{D\text{-}max}$ with that calculated with $LT_{4.0}$. The sample analysed during the study consisted of 19 judoka and 22 MMA practitioners in a preparation period for competition. Each of the two disciplines has its own hierarchy of V_{AT} values. The analysis aimed to determine the effect of the athletic discipline factor and of the method factor on V_{AT} values. Results: The coefficient of variation (CV) values obtained indicate that the effective exercise intensities have bigger variation in judoka aerobic endurance training. V_{AT} values assessed for judoka using different methods for analysing the blood lactate concentration curve are more consistent than in MMA competitors. Conclusions: Judo and MMA competitors have their specific hierarchies of running velocities at the anaerobic threshold, with both the athletic discipline factor and the method factor having an interaction effect on the V_{AT} level. V_{AT} levels assessed from the different methods used to analyse the blood lactate concentration curve are more consistent (ANOM) in judoka than in MMA practitioners.*
Keywords: *Aerobic Endurance, Exercise Intensity, Training Periodization.*

Introduction

Both mixed martial arts (MMA) and judo involve a synthesis of combat techniques performed while standing or on the ground. This results in many similarities between fights conducted according to judo rules and MMA rules, which come down to the repetition of actions involving different shares of static and dynamic work by competitors trying to apply effectively technical and tactical elements specific to their disciplines (Amtmann et al., 2008; Buse, 2006; Glinska-Wlaz, 2016). In stand-up fighting judoka usually use throws, while in

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MMA punches, kicks and strangles prevail. As regards ground fighting in MMA, competitors using judo-like techniques (holds, joint manipulations, strangles) are also allowed to strike their opponents, which is prohibited in judo (Lachlan et al., 2013). When the movements are acyclic and the opponent is active, the athlete's is characterised by varying intensity. According to del Vecchio et al. (2011), the effort-pause ratio (between high-intensity effort and low-intensity effort plus pauses during round) is 1:2 to 1:4. This ratio, lying between ratios typical of judo, i.e. 1:1 to 1:6 (Franchini et al., 2011a) reflects the combination of ground and stand-up techniques. The typical time of a judo bout is about 3 to 4 minutes (Miarka et al., 2012) while most of the MMA matches that involve high-intensity actions predominantly executed during ground fighting end in the third round. A fight has 2 bouts 5 lasting minutes each, while a title fight goes on for 3 rounds. Both types of fight can be extended by another 3 minutes, with a 1-minute break between the rounds. Judo and MMA can be classified as sports involving high intensity, intermittent work. Although a fight in judo or MMA may be ended before its full time (the reasons for such a decision being illegal techniques in both judo and MMA, ippon in judo, and K.O. or T.K.O. in MMA), the probability of an MMA competitor having to work hard for 15 minutes plus the extra time is higher than in judo, where 8 minutes of maximal time including extra time is very rarely observed. A well-recognised time structure of athlete's effort might help select training means consistent with the requirements imposed by potential opponents and the nature of competition itself (Kim et al., 2011). Experts agree that fighting and training in both judo and MMA require comprehensive physical preparation utilizing aerobic and anaerobic metabolic changes that determine athlete's special endurance (Letensky & Harris, 2012). Such recommendations for anaerobic capacity were formulated to use high-intensity intervals for training of MMA athletes based around either the fitness of the athlete or the specificity of MMA rounds and rest periods, but not included any recommendation for aerobic training. The level of aerobic capacity is very important, for anaerobic substrates resynthesis especially between prolonged fights (Franchini et al., 2011a, Franchini et al., 2011b). The similarity of combat sports in terms of VO_2max may be attributed to the non-specific character of this kind of capacity tests (Ahmaidi et al., 1999; Detanico et al., 2012). It can be concluded that the moment of reaching the anaerobic threshold (AT) and the duration of supra-threshold work rate are important indicators of endurance in combat sports. Exercising at work rates above the AT level improves volitional qualities in these athletes, including their resistance to fatigue. Athletes with higher aerobic power are probably able to perform supramaximal activities at a relatively lower intensity compared with those with lower aerobic power (Liparova & Broďani, 2016; Stupnicki et al., 2010). This would be even more important considering the prolonged fights and rest between consecutive stages of tournament (Franchini et al., 2011a). As far as the improvement of aerobic endurance in combat sports athletes is concerned, the recommended group of training means has parameters set with respect to the anaerobic threshold (Sterkowicz et al., 2016). According to Jenkins (2005) "Lactate threshold (LT) is defined as the highest exercise intensity or level of oxygen uptake that is not associated with an elevation in blood lactate concentration. Two lactate thresholds have been distinguished. LT1 generally occurs between 40 and 60 % of maximal oxygen uptake. LT2 generally occurs between 80 and 95 % of maximal oxygen uptake. LT1 is sometimes equated with a blood lactate concentration of 2 $mmol{\cdot}l^{-1}$. LT2 is sometimes equated with a blood lactate concentration of 4 $mmol{\cdot}l^{-1}$. LT2 is also known as onset of blood lactic acid (OBLA). The higher values result from high volume, moderate load, short rest period sequences and circuit-type exercise sessions". Based on the duration of a fight, two research hypotheses were formulated: 1) the AT level is reached faster in judo than in MMA; 2) The diversity of methods used to calculate the AT implies different assessments of endurance used to programme endurance training. The study aimed to determine the differences between exercise intensities at the anaerobic threshold values (V_{AT}) calculated with methods of lactate curve analysis such as LT_{visual}, LT_{loglog}, $LT_{4.0}$, $LT_{\Delta 1}$, and $LT_{D\text{-}max}$, and to build regression equations that allow athletic training specialists to compare V_{AT} values obtained from LT_{visual}, LT_{loglog}, $LT_{\Delta 1}$, $LT_{D\text{-}max}$ with that calculated with $LT_{4.0}$.

Material and methods

Participants. Group 1 – judo competitors (n=19) international and domestic sport level (the group consisted of judoka that had participated in the Olympic Games and World Championships), (mean ±SD) age 21.8 (2.6) years, height 1.75 (0.03) m, body mass 69.4 (3.2) kg, maximal oxygen uptake 58.2 (3.2) $ml{\cdot}kg^{-1}{\cdot}min^{-1}$, length of training experience 11 (1.5) years. Group 2 – MMA competitors (n=22) international and domestic sport level, (mean ±SD) age 27.5 (2.2) years, height 1.79 (0.3) m, body mass 83.1 (5.8) kg, maximal oxygen uptake 56.9 (5.4) $ml{\cdot}kg^{-1}{\cdot}min^{-1}$, length of training experience 8.6 (1.8) years]. The athletes in both groups were in a preparation period for competition. Five methods that are usually used in training practice to analyse the blood lactate concentration curve were selected for the research: LT_{loglog} (Beaver et al., 1985), LT_{visual} (Lundberg et al., 1986), $LT_{\Delta 1}$ (Coyle et al., 1983), $LT_{4.0}$ (Heck et al., 1985), $LT_{D\text{-}max}$ (Cheng et al., 1992). The graded incremental exercise test (GXTs) used in the research meets the exercise intensity requirements of all the five methods (Bentley et al., 2007) as well as allowing the assessment of changes in aerobic endurance performance capacity in the subject. The testing procedure required the subjects to exercise at progressively increasing intensity on the Saturn treadmill (HP Cosmos, Germany). The running speed being initially 8 km h^{-1} was increased by 2 km h^{-1} every 3 minutes, the treadmill incline was set at 1.0 % at all times (Jones & Doust, 2001). In the last 30 s of each exercise grade 20 µl of arterialized blood was sampled from the subject's earlobe to identify blood lactate concentration. Its level was calculated using reagents made by EKF Diagnostics (EKF, Germany) and a Biosen S-line lactate analyser (EKF Germany). Exercise intensity parameters at the lactate anaerobic threshold were determined using software for calculating blood lactate endurance markers. After being informed about the study and test procedures, and any possible risks and discomfort that might ensue, the subjects gave their written informed consent to participate in accordance with the Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects. The research project was approved by the Bioethics Commission at the Local Medical Chamber in Krakow. All computations were performed with the Statgraphics Centurion package v. XVI.I. The normality of distribution (the Shapiro-Wilk test) and the homogeneity of variance between the different methods were controlled for all parameters. The differences between running velocities at the anaerobic threshold (V_{AT}) as obtained with the selected methods were compared using ANOVA, allowing for the athletic discipline factor (2 levels) and the method factor (5 levels). The significance of the differences between pairs of average velocities was assessed using the Tukey's multiple comparison test. A graphical analysis of means (ANOM) was additionally employed to compare average running velocities as yielded by each of the five methods with the grand mean, allowing for decision limits. The Pearson's correlation coefficient between running velocities V_{AT} was calculated. The V_{AT} value calculable with the $LT_{4.0}$ method was obtained from the regression equations. Statistical significance was accepted at $p < 0.05$.

Results

Differences between running velocities at the lactate threshold (LT) as determined from the five methods. The two-way ANOVA revealed significant interaction between both the factors ($F_{(4,204)}$=2.43, p=0.049), (Fig. 1). Both the athletic discipline factor ($F_{(1.204)}$=13.69, p<0.001) and the method factor ($F_{(4.204)}$=7.72, p<0.001) had effect on running velocity V_{AT}. The average V_{AT} as generated by the Tukey's test for judoka (12.7 km·h^{-1}) was significantly lower than that obtained for the MMA competitors (13.7 km·h^{-1}).

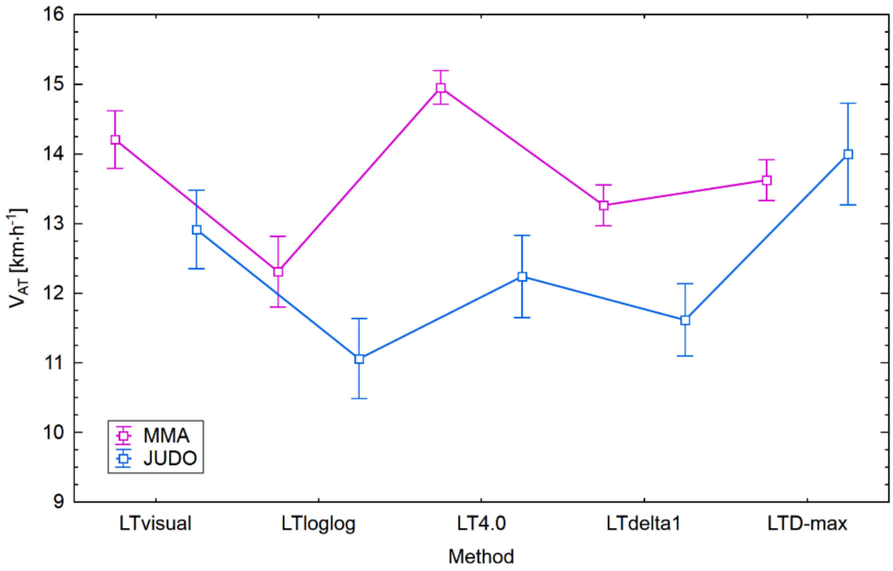

Figure 1. **Interactions and 95 % CI Tukey HSD intervals of V_{AT} for the both judo and MMA groups**

In the judo group, the $LT_{D\text{-}max}$ method produced the highest V_{AT} values and LT_{loglog} the lowest (see Table 1). These athletes were characterised by considerably different running velocities at the anaerobic threshold V_{AT}. At the same time, the coefficient of variation (CV) of running velocity was similar across the V_{AT} calculation methods (see Table 1).

Table 1 **V_{AT} values obtained for judoka by the type of method used to analyse the lactate concentration curve**

Method of estimation AT	Running velocity at the lactate threshold (LT) [km·h^{-1}]				
	Mean	±SD	min	max	CV%
LT_{visual}	12.91	2.47	9.47	19.99	19.09
LT_{loglog}	11.06	2.50	8.94	15.03	22.58
$LT_{4.0}$	12.24	2.58	9.59	15.86	21.08
$LT_{\Delta 1}$	11.62	2.26	8.09	14.62	19.49
$LT_{D\text{-}max}$	14.00	3.18	10.81	19.74	22.74

Note: SD = standard deviation; min-max = range; CV% = coefficient of variation

V_{AT} values in the judo group were significantly dependent on the testing method applied ($F_{(4,90)}=3.46$, $p=0.011$). In two of ten comparisons significant differences between athletes' running velocities at the anaerobic threshold were found (the Tukey's test): $LT_{D\text{-}max}$ - LT_{loglog} and $LT_{D\text{-}max}$ - $LT_{\Delta 1}$. An ANOM graph (Fig. 2) was additionally used to represent graphically average running velocities at the AT calculated with different methods. In this group of athletes, average running velocity yielded by LT_{Dmax} was significantly different from the grand mean.

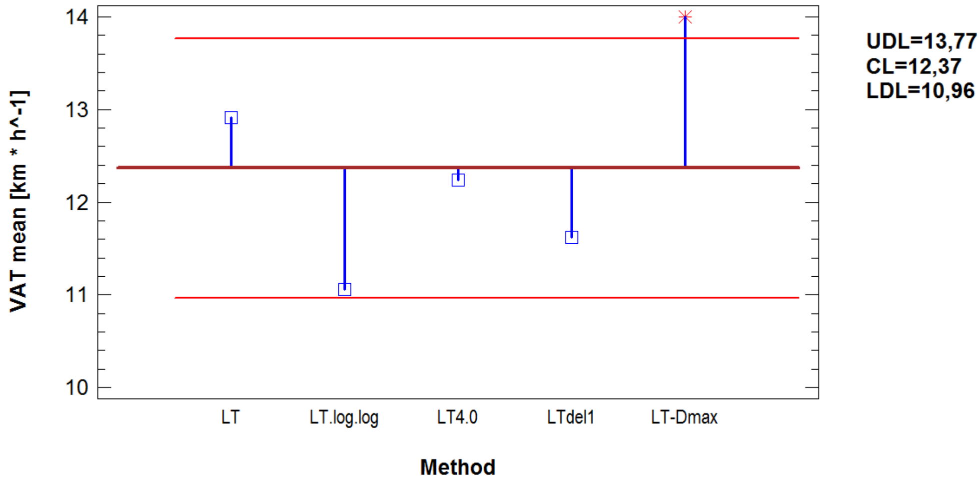

Figure 2. **Analysis of means plot for the judo group with 95 % decision limits. Average V_{AT} attained by the judoka by the testing method**

UDL = upper decision limit, CL = central line (grand mean), LDL = Lower decision limit.

In the MMA group, $LT_{4.0}$ yielded the highest V_{AT} and LT_{loglog} the lowest (see Table. 2). V_{AT} variation was the smallest for the $LT_{4.0}$ results and the greatest for the LT_{loglog} results.

Table 2 **V_{AT} values obtained for MMA by the type of method used to analyse the lactate concentration curve**

Method of estimation AT	Running velocity at the lactate threshold (LT) [km·h^{-1}]				
	Mean	±SD	min	max	CV%
LT_{visual}	14.20	1.93	9.93	17.4	13.61
LT_{loglog}	12.31	2.37	9.03	19.1	19.28
$LT_{4.0}$	14.95	1.13	12.8	17.0	7.54
$LT_{\Delta1}$	13.26	1.38	10.6	15.8	10.37
$LT_{D\text{-}max}$	13.63	1.37	11.3	15.9	10.03

Note: SD = standard deviation; min-max = range; CV% = coefficient of variation

Between the compared pairs of average running velocities at the lactate threshold (LT) obtained from the five methods three statistically significant differences ($F_{(4,105)}$=7.55, $p<0.001$) were found, which were subsequently verified using the Tukey's test: LT_{loglog} – $LT_{4.0}$, LT_{visual} – LT_{loglog}, and $LT_{4.0}$ – $LT_{\Delta1}$.

Running velocity at the V_{AT} level as obtained from the $LT_{4.0}$ method was significantly greater than the grand mean, while that generated by LT_{loglog} was lower (Fig. 3). Correlations between running velocities at the lactate threshold (LT) obtained from the five methods. In the judo group, three methods produced statistically significantly correlated V_{AT} values ($p \leq 0.001$). The LT_{loglog} results were highly correlated with $LT_{4.0}$ (r=0.90) and $LT_{\Delta 1}$ (r=0.87). The V_{AT} values obtained from the $LT_{4.0}$ and $LT_{\Delta 1}$ methods were also highly correlated (0.98).

In the MMA group, V_{AT} values obtained from all methods applied to analyse the blood lactate curve were statistically significantly correlated. Four moderate correlations were found between the values obtained from LT_{visual} – L_{t4} (0.65, $p<0.01$), LT_{visual} – $LT_{\Delta 1}$ (0.52, $p<0.05$), LT_{loglog} – $LT_{\Delta 1}$ (0.69, $p<0.001$), and $LT_{\Delta 1}$ – $LT_{D\text{-}max}$ (0.64, $p<0.001$). Highly correlated results were obtained from LT_{visual} – LT_{loglog} (0.74, $p<0.001$), LT_{visual} – $LT_{D\text{-}max}$ (0.87, $p<0.001$), LT_{loglog} – $LT_{4.0}$ (0.76, $p<0.001$), LT_{loglog} – $LT_{D\text{-}max}$ (0.75 $p<0.001$), and $LT_{\Delta 1}$ – $LT_{D\text{-}max}$ (0.80 $p<0.001$). A very high correlation was found to exist between V_{AT} values generated by $LT_{4.0}$ and $LT_{\Delta 1}$ (0.91, $p<0.001$).

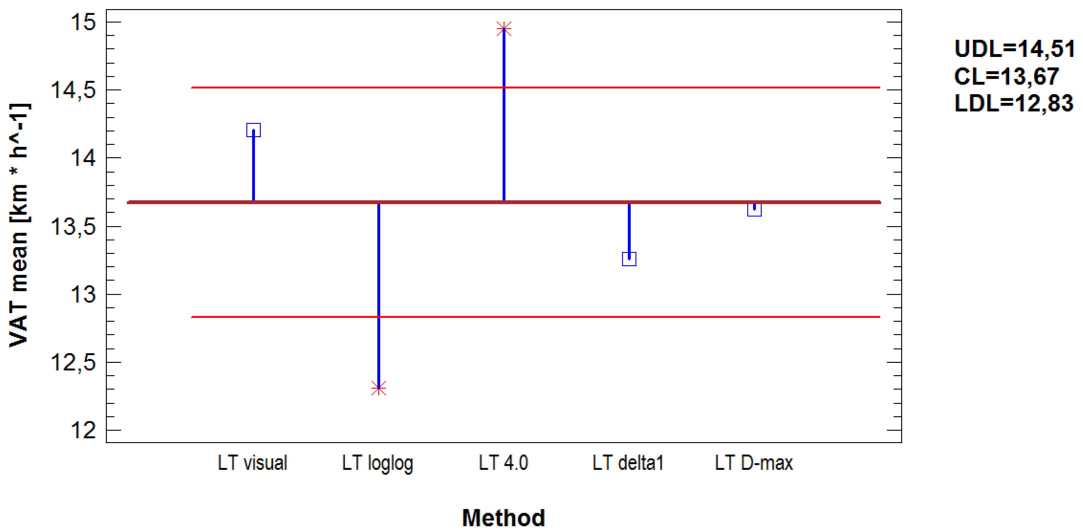

Figure 3. **Analysis of means plot for the MMA group with 95 % decision limits. Average V_{AT} attained by the MMA competitors by the testing method. UDL = upper decision limit, CL = central line (grand mean), LDL = Lower decision limit**

Discussion

The literature dealing with the setting of exercise intensity parameters for combat sports training lacks reports on how methods used to calculate an athlete’s lactate threshold are related. As far other athletic disciplines are concerned, the comparative analyses of the methods used to find the lactate anaerobic threshold divide into two types. One is the comparative analyses of parameter values of the lactate and ventilatory anaerobic thresholds (Cheng et al., 1992; Fabre et al., 2010; Stanula et al., 2013). The other type is studies investigating the parameters of the lactate anaerobic threshold and of maximal lactate steady state (MLSS) (Anuola & Rusko, 1992; Jones & Doust, 1996). The comparative studies conducted by Chwalbinska-Moneta et al. (1989) have demonstrated that compared with the $LA_{4.0}$ method the IAT method (individual anaerobic threshold) produces lower power values at the anaerobic threshold. Comparative analyses of $LA_{4.0}$ and LT_{visual} methods have revealed a similar relation between their threshold power values (Chwalbinska-Moneta et al., 1989). Being able to compare two values of the same parameter that has been determined by analysing changes in blood lactate concentration is vital for athletic training practice. The importance of the issue in triathlete training has been highlighted in the study by McGehee et al. (2005), showing the existence of considerable differences between V_{AT} and HR_{AT} values obtained from laboratory methods and from field methods. However, values produced by $LA_{4.0}$, LT_{visual}, $LT_{D\text{-}max}$, and $LT_{\Delta 1}$ were not found to be significantly different. Davis et al. (2007) have found considerable similarity between V_{AT} values derived from the 0.5 mmol method and the LT_{loglog} method. Another study aimed to identify the LT by four different methods (LT_{visual}, LT_{loglog}, algorithmic adjustment and QLac) during resistance exercise (de Sousa et al., 2012). The LT_{visual}, algorithmic adjustment and LT_{loglog} methods detected the LT at the same intensity. The study conducted by de Sousa et al. (2012) has shown that for the non-athletes exercising on the ergometer power values at the AT level are not significantly different. The results of this study were used to build regression equations that make it possible to determine running velocity at the anaerobic lactate threshold calculable with the $LT_{4.0}$ method using values obtained from LT_{visual}, LT_{loglog}, $LT_{\Delta 1}$, $LT_{D\text{-}max}$ (see Table 3).

Table 3 **Regression equations for determining running velocities at the lactate anaerobic threshold calculable with $LT_{4.0}$ using the results of LT_{Visual}, LT_{loglog}, $LT_{\Delta 1}$, and $LT_{D\text{-}max}$**

Sports discipline	Regression equation	SEE
Judo	$y = 7.19 + 0.431 \cdot LT_{visual}$	1.12
Judo	$y= 1.94 + 0,931 \cdot LT_{loglog}$	1.15
Judo	$y = -0.658 + 1.11 \cdot LT_{\Delta 1}$	0.634
MMA	$y= 9.54 + 0.381 \cdot LT_{visual}$	0.873
MMA	$y = 10.6 + 0.357 \cdot LT_{loglog}$	0.761
MMA	$y = 5.49 + 0.714 \cdot LT_{\Delta 1}$	0.566
MMA	$y = 5.84 + 0.669 \cdot LT_{D\text{-}max}$	0.674

Note: SEE = Standard Error of the Estimate

Conclusion

The regression equations allow athletic training specialists to use the above methods for predicting exercise intensity at the lactate anaerobic threshold calculable with $LT_{4.0}$. This possibility is an important element in the planning of training activities because it allows the specialists to have a standard description of the training programme, as well as making it less probable for training intensity to be too high or too low. Only in the judo group V_{AT} calculable with $LT_{4.0}$ is difficult to predict using the $LT_{D\text{-}max}$ results. The level of endurance expected of an athlete depends on the sport-specific requirements, such as the time structure of a fight, the nature of the effort and opponent's activity. These factors suggest that MMA demands more endurance on the competitors than judo. However, the available research reports fail to provide enough information that might be needed to fully answer the question about whether MMA athletes should have more endurance than athletes practising other combat sports. The question about which combat style originally practised by MMA athletes is best at building their endurance, thus allowing them to take up specialisation in mixed martial arts, has not been answered either. This study and the comparisons of V_{AT} values calculated for judoka and MMA competitors indicates that the levels of aerobic endurance are higher in the latter group. From the perspective of athletic training practice, the proposed regression equations are valuable tools for trainers. V_{AT} values show what intensity range a given training means should have to effectively increase athlete's ability to perform work involving high mobilization of aerobic metabolism with a growing proportion of anaerobic metabolism. Being able to calculate the exact exercise intensities at the V_{AT} allows developing very effective plans for the type of training loads that are crucial for physical preparation in combat sports. The concept proposed in this study makes it possible to utilize different analytical methods which are employed to analyse the blood lactate concentration curve to predict V_{AT} values calculable with $LT_{4.0}$. V_{AT} estimation accuracy within 1 $km \cdot h^{-1}$ is fully acceptable as far as the practical needs of combat sports training are concerned and does not entail the overlapping of training intensity ranges.

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