The interdependence of the main indicators of five methods applied to determine the lactate anaerobic threshold in judo athletes

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Abstract

Background & Study Aim: In the practice of sport training the anaerobic threshold (LT2) is sought using a whole range of methods. As a result, different LT2 values are obtained and applied to programme endurance training. The aim of the research are the relationships between the main indicators of the five methods applied to determine the lactate anaerobic threshold in judo athletes.

Material & Methods: In the study, 19 judoists at international and national sport level going through a preparation period for competition performed a graded incremental exercise test (GXTs) that met the requirements of all five methods. The research used five methods that are usually applied in training practice to analyse the blood lactate concentration curve: LTvisual, LTloglog, LT4.0, LTdel1, and LTD-max. LT2 values generated by LTvisual, LTloglog, LT4.0, LTdel1, and LTD-max methods were used to build regression equations for determining LT2 based on LT4.0 values.

Results: The experiment has showed that judoists, like other athletes, have a specific profile of running velocities at anaerobic threshold. The range of running velocities (VCR) at which their maximal oxygen uptake (VO2max) was recorded points to a relatively wide range of work rates that can be applied to build the aerobic endurance of judoists at similar levels of sport accomplishment. With the exception of LTD-max, the other methods of lactate curve analysis produced very similar running velocities at anaerobic threshold (VAT).

Conclusions: This study shows which methods can be used interchangeably for training purposes without the risk of running velocities being considerably different. It has been found that VLT2 values obtained from LT4.0 method are the most similar to those generated by the other methods.

Keywords: aerobic endurance • aerobic training zone • combat sports • exercise intensity • training periodization

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Ippon – one point. Achieved through the execution of a valid technique on the opponent.

Training intensity – the effort of training. A number of methods are used to establish training intensities which give maximum benefits. These include the lactic acid method, minute ventilation method, and target heart-rate [46].

Exercise intensity – in order to improve physical fitness, exercise must be hard enough to require more effort than usual. The method of estimating appropriate training intensity levels varies with each fitness component. Cardiovascular fitness, for example, requires elevating the heart-rate above normal [46].

Aerobic training zone – the range of training intensities between an individual's aerobic threshold and anaerobic threshold [46]

Training periodization – depending of the phase of periodization plan, the training emphasis will shift to develop specific characteristics and manage fatigue. A truly comprehensive plan includes dietary recommendation and psychological training. If the training plan is not completely integrated, the like hood that the athlete will achieve successful results is significantly decreased. The annual training should contain at least preparatory, competitive, and transition phases [47, p. 146].

Introduction

Among trainers' professional tasks, the planning of the training process and control over the athlete's technical schooling are rated the highest [1]. A judo bout [2] is characterised by sequences of actions involving different amounts of static and dynamic work, which the contestants take to perform techniques and tactical elements specific to their discipline. In the vertical posture, judoists usually use throws [3], while in boxing punches with the hands prevail [4] and in karate kicks are also employed [5-8]. When the movements are acyclic and the opponent is active, work is characterised by varying intensity.

According to Szijan and Niewzorow [9], in judo bout the effort-pause ratio (between high-intensity and low-intensity effort) is 1:1 to 1:6, which reflects the combination of ground (*ne-waza*) and stand-up techniques (*tachi- waza*). Judo is known to be a sport involving high intensity intermittent work. A typical judo bout goes on for about 3 minutes [3], but may end early when one of the contestants has used a prohibited technique or scored an *ippon*. In some cases, extra time extending the bout to maximum 8 minutes is allowed, but these instances are rare [2].

Good knowledge of the effort time structure helps select training means corresponding to opponents' requirements and the character of the competition itself [10]. Experts agree that fighting and training in judo [9] involves comprehensive physical preparation based on aerobic and anaerobic metabolic changes that determine judoists' special endurance [9, 11]. The level of athlete's aerobic capacity is very important, because anaerobic substrates resynthesize especially between prolonged fights [12, 13]. The similarity of combat sports with respect to VO2max may be attributed to the non-specificity of capacity tests. The judoist's aerobic capacity not change significantly during the consecutive periods of a macrocycle [14] or even decreases, while the anaerobic capacity expands [9]. Therefore, the point in time when the anaerobic threshold (AT) is reached and the duration of the supra-threshold work rate are important indicators of the combat athletes' endurance. Exercising at work rates above the AT level improves their volitional qualities, including resistance to fatigue.

Athletes with higher aerobic power are probably able to perform supramaximal activities involving relatively lower intensity than those whose aerobic power is lower. This would be even more important considering the prolonged fights and rest between consecutive stages of a tournament [13]. The recommendable means of improving combat athletes' aerobic endurance have parameters set against the anaerobic threshold. According to Jenkins [15], "Lactate threshold (LT) is defined as the highest exercise intensity of 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" [15, p. 44-45].

The aim of the research are the relationships between the main indicators of the five methods applied to determine the lactate anaerobic threshold judo athletes.

Material and methods

Participants

The subjects (n = 19) were judoists at international and national sport levels who had competed in the Olympic Games and World Championships: mean age (±SD) 21.8 (2.6) years, mean height 1.75 (0.03) m, mean 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]. The judoists were in a preparation period for competition. Having been informed about the purpose of the study and test procedures, as well as all related risks and discomfort, the subjects provided their written informed consents to participate in the experiment as required by the Helsinki Declaration [16].

The research project was approved by the Bioethics Commission at the Regional Medical Chamber in Krakow, no. 118/KBL/OIL/2012.

Methods

The research used five methods that are usually applied in training practice to analyse the blood lactate concentration curve. The methods can be characterised as follows:

LT_{loglog} – the work rate and lactate acid (LA) concentrations in blood are given as logarithms; LT2 is designated by the point where the LA points start deviating upwards from those lying on the regression line which shows changes in blood lactate concentration when exercise intensity is below the AT. The intersection of the line and the regression line for the fast rising values represents LT2 [17].

LT_{visual} – this method assumes that a set of LA concentration values can be described with respect to the work rate through an exponential model (a continuous method). The anaerobic threshold is found by projecting on the effort intensity axis the point where the exponential (lactate) curve and the tangent plotted at 45° intersect [18].

LT_{del1} – the work rate at the anaerobic threshold is represented by exercise intensity making blood lactate concentration increase by 1 mmol·l^{-1} [19].

$LT_{4.0}$ – the work rate at the anaerobic threshold is given by exercise intensity at which blood lactate concentration increases above 4 mmol·l^{-1} [15, 20, 21].

$LT_{D\text{-}max}$ – the work rate at the anaerobic threshold is established by projecting on the exercise intensity axis this point on the interval connecting the extreme points of the lactate curve that lies the farthest from the curve [18, 22].

The graded incremental exercise test (GXTs) used in the experiment complied with exercise intensity requirements posed by all five methods [23, 24]. It also allowed changes in aerobic endurance performance capacity of the subjects to be evaluated [25]. The testing procedure required the subjects to exercise at progressively increasing intensity on the Saturn treadmill (HP Cosmos, Germany). The initial running speed of 8 km·h^{-1} was being increased by 2 km·h^{-1} every 3 minutes and the treadmill incline was set at 1.0% at all times [26, 27].

In the last 30s of each exercise grade, 20 µl of arterialized blood was sampled from the subjects' earlobes and processed by reagents made by EKF Diagnostics (EKF, Germany) and the Biosen S-line lactate analyser (EKF Germany) to determine blood lactate concentrations. The exercise intensity parameters at the lactate anaerobic threshold were determined with software used to calculate blood lactate endurance markers [28]. Code is available to calculate the various markers described above in the form of an Excel template (Microsoft® Excel 2003) and as a function in R, a freely available statistics package (http://www.cran.r-project.org). The software is available for download (http://www.nuigalway.ie/maths/jn/Lactate) and includes a tutorial page for each platform.

Statistical analysis

All computations were performed with the Statgraphics Centurion package v. XVI.I. Because the assumption about variance homogeneity was not met (Levene's test = 4.605, $p = 0.002$), the differences between judoists' running velocities at anaerobic threshold (V_{LT}) were derived from the Kruskal-Wallis non-parametric test; the effect of factor-named methods (5 levels) was also identified. The Spearman's rank coefficient of correlation between the values of V_{LT} was calculated. Because results of $LT_{D\text{-}max}$ not met normality assumption it was excluded from regression analysis. The level of statistical significance was taken at $p<0.05$.

Table 1. Running velocities (km·h^{-1}) of the judoists (n = 19) at LT2 obtained from the different methods of lactate curve analysis

Method	Average	Median	SD	CV	Min	Max	Range
$LT_{D\text{-}max}$	14.00	12.69	3.184	22.74%	10.81	19.74	8.93
$LT_{log.log}$	11.59	11.25	1.574	13.59%	8.33	15.03	6.70
$LT_{4.0}$	12.77	11.88	1.52	11.90%	11.1	15.86	4.76
LT_{del1}	12.14	11.67	1.257	10.35%	10.44	14.62	4.18
LT_{visual}	12.91	11.99	2.465	19.09%	9.47	19.99	10.52

CV-coefficient of variation

Results

Differences between judoists' running velocities at lactate threshold (LT2) provided by the five methods.

The running velocities V_{LT2} (km·h^{-1}) had significantly different medians depending on the method used to designate LT2 (Kruskal-Wallis test statistic = 9.99, p = 0.041, Table 1). $LT_{D\text{-}max}$ and $LT_{log.log}$ produced, respectively, the highest and the lowest V_{LT2} (km·h^{-1}) (Table 1). The judoists were found to have significantly different running velocities at the anaerobic threshold (V_{LT2}), but the coefficients of variation (CV) of running velocity were similar for all methods used to determine V_{LT2}.

Figure 1 shows five box-and-whisker plots, one for each V_{LT2} method. The lines inside each box indicate the position of the sample medians (the dots stand for the means). The whiskers extend from the box to the minimum and maximum values in each group.

The area covered by each notch represents uncertainty in estimating the median of the group. As the notches for the pairs of medians in $LT_{D\text{-}max}$ $LT_{log.log}$ and $LT_{D\text{-}max}$ - LT_{del1} do not overlap, the medians are statistically significantly different at a confidence level of 95%.

Correlations between judoists' running velocities at lactate threshold (LT2) provided by the five methods.

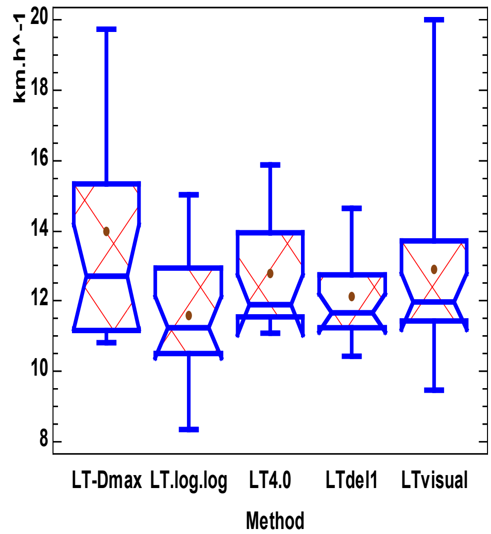

Figure 1. Box-and-whisker plots, one for each V_{LT2} method.

Three methods provided statistically significantly correlated values of V_{LT2} ($p \leq 0.03$) – the LT_{visual} results were strongly correlated with those obtained from $LT_{4.0}$, $LT_{log.log}$ and LT_{del1}. The correlation between V_{AT} values generated by $LT_{4.0}$ and LT_{del1} was also high (0.88) Running velocities at anaerobic threshold determined with $LT_{log.log}$ and LT_{del1} were moderately correlated. The correlation between velocities derived from $LT_{D\text{-}max}$ and the other methods was not significant. $LT_{D\text{-}max}$ method was not used in regression equations (Table 3).

Table 2. Spearman Rank Correlations (sample size = 19) between indicators

Method of estimation V_{LT}	LT_{visual}	LT_{40}	$LT_{log.log}$	LT_{del1}
LT4.0	0.8772			
	0.0002			
$LT_{log.log}$	0.8878	0.7224		
	0.0002	0.0022		
LT_{del1}	0.7193	0.8825	0.5218	
	0.0023	0.0002	0.0268	
$LT_{D\text{-}max}$	0.2614	0.0702	0.3528	0.0737
	0.2674	0.7659	0.1344	0.7546

Correlation
p-value

Table 3. Regression equations using LT_{Visual}, LT_{loglog}, LT_{del1} values to calculate running velocities at lactate anaerobic threshold corresponding to $LT_{4.0}$.

Regression equation	SEE
$y = 7.19 + 0.431 \cdot LT_{visual}$	1.12
$y = 1.94 + 0.931 \cdot LT_{log.log}$	1.15
$y = 0.658 + 1.11 \cdot LT_{del1}$	0.634

SEE- standard error of estimation

DISCUSSION

The literature dealing with the selection of exercise intensity indicators for combat sports training lacks studies on the relationships between methods used to locate the lactate threshold. In other disciplines, the comparative studies of the methods form two groups: one compares the indicators of the lactate and ventilatory anaerobic thresholds [29-31] and the other one investigates the indicators of the lactate anaerobic threshold and of maximal lactate steady state (MLSS) [32, 33].

The existing studies on judoists assume that VO_2max is represented by its values recorded at anaerobic threshold [11, 34, 35]. As far as the practice of sport training is concerned, VO_2 values at metabolic thresholds are not useful. Proven indicators showing the work rate to be moving between metabolic thresholds are necessary instead, such as those based on lactate curve analysis [36-40]. Tests seeking to locate the lactate anaerobic threshold have been studied for many years now [41-43].

The comparative studies conducted by Chwalbińska-Moneta et al. [44] have demonstrated that the IAT method (individual anaerobic threshold) yields lower power values at the anaerobic threshold than $LA_{4.0}$. Chwalbińska-Moneta [45] has found a similar relation between the threshold power values obtained from $LA_{4.0}$ and LT_{visual}. The V_{LT2} values obtained from the particular methods (excluding LT_{D-max}) in this study were not significantly different from each other. The most common method in training practice is $LT_{4.0.}$ So, we propose regression equations that can use values obtained from LT_{visual}, $LT_{log.log}$, LT_{del1} to calculate running velocities at AT equivalent to those produced by $LT_{4.0}$.

The regression equations allow coaches to use whichever of the four methods to find exercise intensity at the lactate anaerobic threshold equivalent to that obtainable with $LT_{4.0}$. Having this option is important for planning training activities, as it allows the specialists to have uniform descriptions of training programmes and reduces the probability of training intensity being set too high or too low. The target endurance of judoists depends on the demands of their discipline, such as the time-motion structure of a fight, the nature of the effort and opponent's activity. However, the existing research reports do not provide sufficient information to determine explicitly whether judoists need more endurance than other combat athletes.

The presented regression equations are valuable practical tools for coaches. V_{LT2} values serve as an indication of the intensity range of training means that effectively increase athlete's capability of performing work boosting aerobic metabolism with an increasing proportion of anaerobic metabolism. Having a precise tool for calculating V_{LT2} allows effective planning of particular types of training loads, which is a crucial element in the physical preparation of a combat sport athlete. The proposed approach allows different methods for analysing the blood lactate concentration curve to be used to arrive at V_{LT2} values obtainable from $LT_{4.0}$. The estimation accuracy of V_{LT2} ~ 1 $km \cdot h^{-1}$ is fully acceptable for practical purposes of combat sports training and does not cause the overlapping of training intensity ranges.

PRACTICAL APPLICATIONS

Major differences between running velocities at which the judoists' maximum oxygen uptake (vVO_{2max}) was recorded signify considerably different work rates at which the athletes' aerobic metabolism is the highest. This makes it rational to seek tools enabling a very precise selection of load indicators for building the aerobic endurance of the elite judoists.

A motor-skills training programme must be individually adjusted. A training programme employing uniform work indicators (e.g. running velocity) which usually is applied in general preparation period in the case of some athletes, different results than those intended. In the practice of sport training the variety of methods used to designate the anaerobic lactate threshold (LT2) should not contribute to inconsistent load indicators. Particular approaches to analysing the blood lactate concentration curve yield dissimilar exercise intensities at the lactate anaerobic threshold, thus making training methodology less efficient.

Exercise intensity in aerobic endurance training of combat athletes at similar levels of achievement can be set very differently. Different V_{LT2} values that have been obtained in this study from particular methods for locating the lactate anaerobic threshold point out that special attention must be given to the individualization of training loads. The proposed regression equations allow estimate $LT_{4.0}$ velocity from the results obtainable in other methods. As a result, training intensity can be programmed based on the same criteria.

Conclusions

This study shows which methods can be used interchangeably for training purposes without the risk of running velocities being considerably different. It has been found that V_{LT2} values obtained from $LT_{4.0}$ method are the most similar to those generated by the other methods. The range of SEE is the smallest when the running velocity indicators ($LT_{4.0}$) are determined from (LT_{del1}). With the exception of LT_{Dmax}, the other methods produced consistent values of V_{LT2}.

Highlights

A training programme employing uniform work indicators (e.g. running velocity) which usually is applied in general preparation period. Exercise intensity in aerobic endurance training of combat athletes at similar levels of achievement can be set very differently. Different V_{LT2} values that have been obtained in this study from particular methods for locating the lactate anaerobic threshold point out that special attention must be given to the individualization of training loads. The proposed regression equations allow estimate $LT_{4.0}$ velocity from the results obtainable in other methods.

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