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EFFECTS OF 8 WEEKS RESISTANCE TRAINING ON PEAK RUNNING VELOCITY AND HEART RATE DEFLECTION POINT IN SEDENTARY WOMEN

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Abstract:

Purpose: Resistance training can result in increased lean mass, maximal strength, muscular power and facilitates similar acute physiological responses and chronic physiological adaptations to traditional aerobic exercises. This study aimed to determine the effects of resistance training on PV and VHRDP in sedentary women. **Methods:** Sixteen sedentary women were distributed in control group (CG) and Resistance Training Group (RTG). The RTG underwent a training program for major muscle groups four times a week over a period of 8 weeks which consisted of four sets of 8-12 repetition per set. The GC was asked to maintain their usual routines. Participants performed an incremental treadmill test conducted to voluntary exhaustion before and after intervention to assess peak velocity and heart rate performance curve. **Results**: A 2 (group: RTG, CG) x 2 (time: pre, post) ANOVA revealed a significant interaction for PV ($p<0.01$) and a trend to VHRDP ($p=0.082$). A significant main effect of time was found for

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PV (p=0,0038) and VHRDP (p=0,038). RTG presented a significant increase in the peak velocity (11,65±1,6 vs 13,50±1,5 $km.h^{-1}$; $p<0.01$) while CG showed no difference (11,12±0,83 vs 11,00±0,92 $km.h^{-1}$). RTG significantly improved VHRDP (9,8±1,1 vs 11,2±1,2 $km.h^{-1}$; $p<0.01$) and CG did not (9,1±0,6 vs 9,3±1,3 $km.h^{-1}$). **Conclusions:** The resistance training applied led to improvement in peak velocity and velocity at heart rate deflection point. RT should be prescribed by coaches and instructors as a viable exercise modality to improve aerobic fitness in sedentary females.

Keywords: resistance training, peak running velocity, heart rate deflection point

1. Introduction

Maintenance of strength throughout the lifespan may reduce the prevalence of functional limitations and by this reason, current guidelines encourage all adults, in addition to increasing aerobic activity, to include activities that increase muscular strength (Ratamess et al. 2009). Although Resistance Training (RT) programs may be effective in stimulating performance improvements, gains in muscular strength, increase hypertrophy and decrease sarcopenia, during the last decade, increased attention has been given to the effects of prescribing RT to improve aerobic fitness (Alvehus et al. 2014). Hollings et al., (2017) evaluated the effect of progressive RT on cardiorespiratory fitness and muscular strength in coronary heart disease patients and showed that aerobic fitness (VO_{2max}) improved similarly after either progressive RT (16.9%) or aerobic training (21.0%). Alvehus et al. (2014) found significant increases in the expression of the genes Adipor1 and cOX4 in skeletal muscle after 8 weeks of RT, which resulted in significant gains in lean mass, maximal oxygen consumption (VO_{2max}) and fat oxidation. In the same line, a significant increase in VO_{2max} (by 17 %) was found only in a strength-endurance training group (compared to strength and endurance training group alone) during a 21-week period (Mikkola et al., 2012).

Besides VO_{2max}, a number of criteria have been accepted as indicators and predictors of aerobic performance, e. g. the lactate threshold (LT), maximal lactate steady state (MLSS) and onset of blood lactate accumulation (OBLA) (Czuba et al., 2009). However, VO_{2max}, LT and OBLA determination requires expensive equipment and complex or invasive laboratory procedures and these limitations decrease access to exercise testing. More simple and less expensive tools related to exercise intensity might be useful to predict these metabolic thresholds. Therefore, some authors have proposed methods for noninvasively determining these physiological thresholds, based on the HR response during incremental exercise (Conconi et al., 1982b), Ventilatory Threshold (VT) (Ahmaidi et al., 1993) and rate of perceived exertion (Moreira et al., 2010).

Among these, a method advocated for prescribing OBLA exercise training intensity is based on heart rate deflection point (HRDP). The rationale for this method is based on the premise that the response of heart rate (HR) to incremental exercise is not always linear but shows a break point in the HR-intensity curve (Conconi et al., 1982a;

Delevatti et al., 2015). Furthermore, the intensity at the second physiological threshold, established by means of blood lactate or ventilatory measurements, may be coincident to the intensity at HRDP (Vachon et al., 1999; Alberton et al., 2010; Delevatti et al., 2015).

Peak velocity (PV) during incremental exercise, is the maximum speed achieved and is associated with VO_{2max} (Mclaughlin et al., 2010). Thus, PV is an attractive variable that has become popular among researchers, trainers and endurance runners due to its practicality and technical and financial accessibility and it can be used to prescribe individualized physical training (Fernandes-da-Silva et al. 2016). It has been shown that training prescribed by PV promoted similar improvements compared to training prescribed by velocity associated to VO_{2max} (vVO_2max) (Manoel et al., 2017).

Given the potential of these variables for exercise prescription, it seems reasonable to further study the effects of different exercise training regimens on these variables. It has been documented that aerobic continuous training above LT may be important for eliciting an increase of oxygen consumption (VO_2) at LT (Henritze et al., 1985). Previous research using Muscular Endurance Resistance Training (MERT) in aerobically trained individuals has shown improvements in lactate kinetics via an increase in the power output and percentage of VO_{2max} at which OBLA occurred during an incremental exercise test (Lantis et al., 2017; Farrell III et al., 2018).

Whether some findings indicate that RT improves VO_{2max}, LT and OBLA in trained male individuals, it would be interesting to investigate the effects of a RT program on HRDP and PV in sedentary women. It can be speculated that performing RT, which has been shown to improve OBLA and VO_2max, should increase PV and VHRDP. Therefore, the purpose of the current study is to examine the adaptations of both treadmill PV and velocity at HRDP to a mesocycle (8 weeks) of RT. We hypothesized that PV and VHRDP would significantly improve after the mesocycle of RT.

2. Material and Methods

2.1 Study Design

Sixteen sedentary women served as subjects. Eight women were assigned to a RT group, which participated in RT 4 times/week, and the remaining eight comprised the control group (GC). The RTG performed an 8-week RT training program. The CG continued their regular daily physical activity. None of the subjects had participated in any systematic exercise training for 6 months prior to start of the study, based on self-reported physical activity questionnaire. Informed consent was obtained from all individual participants included in the study. All testing and training were completed in a gym at a temperature 20-25˚C. Prior to and following the 8 weeks training period both groups performed an incremental exercise test to determine PV, HRDP and VHRDP.

2.2 Participants

Participants were sedentary women (age 28 ± 3 yr, height 162.9 ± 6.3 cm, weight 58.7 ± 6.2 kg, body fat 26.8 ± 4.5%) who had not participated regularly in RT. To be included in the study, participants were required to be 18 - 35 years old and not have musculoskeletal or cardiometabolic disorders. They were assigned to RTG (n=8), with participants performing an 8-week dynamic resistance training program and CG (n=8) with participants not engaging in any physical exercise. The study protocol, methods and appropriate informed consent were approved by the University of Southern Santa Catarina State Ethics Committee.

2.3 Exercise Testing

PV and VHRDP were measured in two test sessions using a progressive exercise protocol on a treadmill. The tests were performed before randomization (base-line) and after 8 weeks in both groups. All evaluations were conducted at the same time of the day under similar conditions. At the beginning, velocity was set as 4 $km.h^{-1}$ (0% slope) and was increased by 1 $km.h^{-1}$ every minute up to volitional exhaustion. There was a certain transition speed from walking to running in order to provide a reasonable number of stages to further HR analysis. PV was determined as the highest velocity subjects could maintain for a complete stage plus the interpolated velocity from incomplete stages (Kuipers et al., 1985). Strong verbal encouragement was given throughout all tests. Heart rate (HR) was monitored continuously (Speedo Stainless Steel Back, Jest 80565G0EPNP). From the HR data, three-order polynomial regression curve of the heart rate vs. time was traced in order to compute the maximum distance between the straight line formed by the two end points of HR in each curve, the mathematical model of “Parallel Straight Line Slope” was implemented. In this model, there is only one point in the polynomial HR-Time curve with the maximum distance from the two end points straight line. A minimal HR values equivalent to 140 b/ min was used to fit the curve. The most distant point on the curve to the line was considered as the HRDP and the corresponding running velocity value was set as VHRDP (Siahkouhian and Meamarbashi, 2013).

2.4 Resistance Training Protocol

Training was carried out 4 times a week for 8 weeks. Exercises used for RT are shown in Table 1 and the training mesocycle set for 8 weeks is demonstrated in table 2. Adherence to the RT was high, with all women completing all training sessions. An investigator supervised the participants at all workouts. The training program was designed using guidelines from the American College of Sports Medicine’s position stand “Progression models in RT for healthy adults” (Ratamess et al., 2009). The concept of the training program was to train every major muscle group two times per week for 8 weeks, performing 8–12 repetitions at an eccentric/concentric time of 2/2 s, for 4 sets, with 45 s of rest between sets of each exercise.

The 10 repetitions maximum test (10RM) was used to estimate initial training intensity given the lack of RT experience of the subjects (Simão et al., 2005) It was previously demonstrated that 10 RM load test, although works with maximum intensities, did not generate an exacerbated post-exercise sympathetic activity. Thus, it seems to be safe for cardiovascular healthy or sedentary individuals (Monteiro et al.

2018). The assessment included a warm-up consisting of 2 sets of 15 repetitions at 30% of body mass with 30 seconds between sets. An initial weight was selected to be approximately 50 to 70 % of the participant's perceived capacity. The weight was increased incrementally until a weight that could be lifted 10 but not 11 times was achieved. Five minutes of rest were given between each attempt.

The initial training intensity for RTG was set as 80% of the 10RM load during the first week. If an individual was able to complete four sets of 12 repetitions after 2 weeks (8 training sessions) the training weight was increased 3 – 5% to compensate for strength gains (Kraemer and Ratamess, 2004). If participants were unable to complete 4 sets of 12 repetitions after two weeks the training weight was kept the same.

Table 1: Exercises for RTG program and training types A, B, C, D

A	B	C	D
Pulldown	Back Squat	Chest Press (Machine)	Back Squat
Prone barbell row	Leg press 180º	Declined Bench Press	Leg press 45º
Lat Pulldown	Romanian Dead Lift	Dumbbell Fly	Leg Extension
Barbell Bíceps Flexion	Leg Curl	Triceps Pushdown (cable)	Dead Lift
Alternated dumbell bíceps flexion		Overhead Triceps Extension	

Table 2: Training Mesocycle set for 8 weeks

Week	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
1	A	B	off	C	D	off	off
2	B	A	off	D	C	off	off
3	A	B	off	C	D	off	off
4	B	A	off	D	C	off	off
5	A	B	off	C	D	off	off
6	B	A	off	D	C	off	off
7	A	B	off	C	D	off	off
8	B	A	off	D	C	off	off

2.5 Statistical Analyses

Statistical analysis was carried out using the statistical package SPSS Version 21.0 (IBM Corp., Armonk, NY, USA). The Gaussian distribution for the data was verified by the Shapiro-Wilk goodness-of-fit test (Z value < 1.0). Data are presented as means ± SD. Independent t-tests were utilized to determine if significant between group differences existed for subject characteristics. The data were found to be normally distributed. To determine differences in physiological variables between groups at pre- and post-training a two-way repeated measures analysis of variance (ANOVA) (time and group as factors) was utilized. If the ANOVA reached significance, a Bonferroni-post hoc analysis was performed. Cohen's *d* effect size was used for a better practical description. The Cohen's *d* effect size to repeated measures was applied according to the equation $d = \{[(M1 - M2)] / [(SD1 + SD2)/ 2]\}$ Effect size values (d) were classified as: 0.0 to 0.19 = trivial; 0.20 to 0.59 = small; 0.60 to 1.19 = moderate; 1.20 to 1.99 = large; 2.00 to 4.00 = very large (Hopkins et al., 2009). The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

3. Results

The physiological measurements from the incremental exercise test are summarized in Table 3. Following the study intervention, a significant main effect of time was found for PV ($F_{1,15}$ = 7,061; p=0,003833). Post hoc analysis indicated that the PV increase in the RTG was significant (t= -5,017; p=0,0015) and were not significant in CG (t= 1,000; p=0,35;). A significant main effect of time was found for VHRDP ($F_{(1,15)}$ = 5,175; p=0,038). The VHRDP increased significantly in the RTG (t= -4,08; p=0,004) but did not increase significantly in the CG (t=-0,22; p=0,820). The observed HR at HRDP did not show any significant changes for RTG or CG.

Table 3: PRE to POST changes in physiological measures

Variable	Time	RT group (mean±SD)	CG (mean±SD)	Main Effect	Interaction Between Groups
PV ($km.h^{-1}$)	pre	11,65±1,6	11,12±0,83	FA: F(1,15) = 7,061 p=0,03	F(1,15) = 11,14 p =0,0045
	post	13,50±1,5*ψ	11,00±0,92	FB: F(1,15) = 0,0553 p=0,8173	
VHRDP ($km.h^{-1}$)	pre	9,8±1,1	9,1±0,6	FA: F(1,15) = 5,175 p=0,038	F(1,15) = 3,472 p=0,082
	post	11,2±1,2*	9,3±1,3	FB: F(1,15) = 0,0591 p=0,8211	
HRDP (bpm)	pre	177±8	176±3	FA: F(1,15) = 1,311 p=0,3044	F (1,15) = 0,0122 p=0,91
	post	181±6	180±15	FB: F(1,15) = 0,00001 p=0,992	

FA – Factor time; FB - Factor training; *significantly higher than pre (p<0,01); ψ significantly higher than CG (p<0,01); PV – Treadmill peak Velocity; VHRDP – Velocity at Heart Rate Deflection Point; HRDP – Heart Rate Deflection Point.

As shown in table 4 the mean increase in PV was significantly greater on RTG than in CG (14,7% vs -1,1%,). The mean increase in VHRDP was significantly greater in RTG than in CG (15,4% vs 1,04%).

Table 4: Effect Size changes in physiological measures between groups

Variable	Group	Pre	Post	Mean change (%)	Effect Size d (Cohen)
PV	RTG	11,65±1,6	13,50±1,5*ψ	14,70	1,05 (moderate)
($km.h^{-1}$)	CG	11,12±0,83	11,00±0,92	1,10	0,14 (trivial)
VHRDP	RTG	9,8±1,1	11,2±1,2*	15,40	1,25 (large)
($km.h^{-1}$)	CG	9,1±0,6	9,3±1,3	1,04	0,12 (trivial)
HRDP	RTG	177±8	181±6	3,00	0,45 (small)
(bpm)	CG	176±3	180±15	2,00	0,24 (small)

*significantly higher than pre (p<0,01); ψ significantly higher than CG (p<0,01).

4. Discussion

The most important findings of this study were the significant improvements in treadmill peak velocity and velocity at heart rate deflection point among sedentary women after 8 weeks of dynamic resistance training. To the authors' knowledge, this is the first study that investigated the effects of a RT on peak velocity and heart rate deflection point in sedentary females. Previous investigations that have examined the effects of RT in healthy young men suggested that RT can be used to improve VO_{2max} (Alvehus et al., 2014) and OBLA (Farrell et al. 2016), which lead to the speculation that RT may elicit improvements in PV and VHRDP in other populations, such as sedentary women. The rise in PV (14.7%) is in line with earlier observations (Millet et al., 2002) in which vVO_{2max} improved 2.6% when fifteen triathletes were assigned to endurance-strength (ES) training focused of the quadriceps, hamstring, and calf muscles using 3-5 sets to failure (3–5 reps per set) for 14 weeks. Similarly, Beattie et al. (Beattie et al., 2017) reported a 4.0% in vVO_{2max} increase after a 40-week heavy strength training intervention in trained runners.

It can be suggested that supplementing endurance training with RT may provide improvements to running economy (RE), Time Trial performance and anaerobic parameters such as maximal sprint speed (Blagrove et al., 2018). Generally, the improved RE results in altered running mechanisms predominantly related to intra-muscular co-ordination and increases in tendon stiffness, which may contribute to optimizing force–length-velocity properties of muscle (Dalleau et al., 1998). Tendons are also highly adaptable to mechanical loading and have been shown to increase in stiffness in response to RT (Kubo et al. 2002). Improved tendon stiffness allows the body to store and return elastic energy more effectively, which may result in a reduction in muscle energy cost due to a greater contribution from the elastic recoil properties of tendons (Arampatzis et al., 2006). Improvements in PV observed in our study following a hypertrophy-type RT may be due to an enhanced utilization of elastic energy during the running test and improved running economy.

Another possible explanation for improved PV could involve muscle fiber type conversion. Staron et al., (Staron et al., 1991) found a decrease in the percent of fast glycolitic type IIB fibers, with a simultaneous increment in percent of fast oxidative glycolitic type IIA fibers after a RT program in women, which led to significant hypertrophy of all three major fibers types after 20 weeks of RT. (Staron et al., 1991). Because the type IIa fibers are more oxidative than type IIb fibers, a decrease in percentage of type IIb and an increase in the percentage of type IIa fibers may lead to an increase in the oxidative capacity of strength trained muscle. Frontera et al., (Frontera et al. 1990) found an increase in capillary per fiber ratio and citrate synthase activity in the vastus lateralis muscle after older men performed RT. High intensity RT also appears to improve time to exhaustion during cycle ergometer and treadmill exercise, but without altering VO_2max (10). Similar results were observed by Hickson et al. (Hickson et al. 1988) who observed that adding heavy resistance training to already cycle/run trained subjects improved performance both in the short term (4-8 min) and longer term (50 min) without causing changes in VO_{2max}. Thus, it can be inferred that a possible hypertrophy of type I and IIa muscle fibers, increased respiratory enzyme activity and oxidative capacity after a 8 week RT may have contributed to an augmented PV and VHRDP in our study.

The VHRDP also increased after the RT. As the HRDP is reputed to be a noninvasive method to assess the anaerobic threshold, this implies that physiological variables such as power, speed, HR, blood lactate or VO_2 at the HRDP and the anaerobic threshold should be highly related (Bodner and Rhodes 2000). HR and work intensities related to the HRDP appear to be modified by training, detraining and illness (Ballarin et al., 1989). This suggests that HRDP may indicate changes in training status over time and the relative effectiveness of training programs implemented. According to previous findings, there is also an agreement between HRDP and several physiological thresholds such as OBLA , LT2, VT2 (Delevatti et al., 2015) and Second Heart Rate Variability Threshold (Buchheit et al., 2016). Researchers have demonstrated that in the general population, aerobic training often improves the exercise intensity corresponding to anaerobic threshold without a concomitant increase in VO_{2max} (Sjodin et al., 1982). Additionally, recent studies have established a new method for the improvement of OBLA utilizing RT with lighter loads and higher repetitions, termed muscular endurance resistance training (MERT). This strategy appears to lead to improvements in power output and VO_2 at which OBLA occurs during cycling following 8 weeks of MERT (Farrell et al. 2016; Lantis et al., 2017). Traditional concepts indicate that the threshold point should correspond to the capacities and limitations of the cardiopulmonary system as well as the optimal supply of energy using cytosol and mitochondrial enzymatic activities. Although both VO_{2max} and LT2 are often used to express cardiovascular fitness, the two measurements appear limited by different mechanisms by which VO_{2max} is controlled by maximal cardiac output, while skeletal muscle metabolism plays more of a role in determining submaximal exercise performance through biochemical and oxidative adaptations (Ivy et al., 1980).

The HRDP appears to be a multifactorial phenomenon in which each of the following factors may play a certain role in humans with a wide range of fitness levels: myocardial function (expressed as Left Ventricular Ejection Function), individual variations in autonomic HR regulation, heart dimensions (thickness of both left ventricular posterior and interventricular walls) and blood K^+ (Hofmann et al. 1994).

Metabolic acidosis occurring at high workloads could indeed facilitate the release of oxygen from haemoglobin (the Bohr effect) and thus improve cardiocirculatory efficiency and attenuate the increase in HR. The RT applied in our study might reasonably have delayed recruitment of type II muscle fibers throughout the incremental exercise test, brought on by a likely increased muscle strength, hypertrophy and aerobic capacity. In the same manner, glycolytic pathways may have been activated in later stages of the run when compared to pre-training, which may have led to alterations at the point which acidosis influenced myocardial function to induce HRDP. Other authors (Alvehus et al., 2014), applied resistance training (2-4 sets, 8-15 reps performing each exercise to concentric failure) for 8 weeks and showed a substantial increase in lean mass along with a significant increase in VO_2 peak, rate of fat oxidation, and moderate increases in expression of the genes encoding Adipor1 and cOX4 in skeletal muscle, suggesting that the working muscle adapted to utilize fatty acids as substrates. Although no measurements were carried out to directly evaluate these physiological and biochemical variables in our study, these adjustments and possible improvements of the second lactate turnpoint might be an explanation to an increased VHRDP.

The present study has some limitations. First, the randomness in sample selection and the small number of participants limit the inference of results. Secondly, the results may be conditioned to the specific type of RT, while the other studies with different exercises are needed to verify if they are sufficient in the studied variables will be consistent. Furthermore, other important variables and behaviors which might influence the results such as hydration, sleep and nutritional status were not controlled in our study design.

5. Conclusion

In summary, 8 weeks of whole body dynamic RT improves treadmill running peak velocity and velocity of heart rate deflection point in sedentary women. Furthermore, the RT protocol presented in this study may be regarded as an effective approach to improve aerobic parameters in situations where traditional forms of aerobic exercise may not be viable, accessible or appropriate.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval

All procedures performed in studies involving human participants were in accordance with the ethical Standards of the institutional or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical Standards. This article does not contain any studies with animals performed by any of the authors.

Informed consent

Informed consent was obtained from all individual participants included in study

References

Ahmaidi, S., Hardy, J., Varray, A., Collomp, K., Mercier, J., and C., P. 1993. Respiratory gas exchange indices used to detect the blood lactate accumulation threshold during an incremental exercise test in young athletes. Eur. J. Appl. Physiol. Occup. Physiol. 66: 31–36.

Alberton, C., Kanitz, A., Pinto, S., Antunes, A., Finatto, P., Cadore, E., and Kruel, L. 2010. Determining the anaerobic threshold in water aerobic exercises: a comparison between the heart rate deflection point and the ventilatory method. J Sport. Med Phys Fit. 53: 359–367.

Alvehus, M., Boman, N., Söderlund, K., Svensson, M.B., and Burén, J. 2014. Metabolic adaptations in skeletal muscle, adipose tissue, and whole-body oxidative capacity in response to resistance training. Eur. J. Appl. Physiol. 114(7): 1463–1471. doi:10.1007/s00421-014-2879-9.

Arampatzis, A., De monte, G., Karamanidis, K., Morey-Klapsing, G., Stafilidis, S., and Bruggemann, G. 2006. Influence of the muscle–tendon unit's mechanical and morphological properties on running economy. J. Exp. Biol. 209(17): 3345–3357. doi:10.1242/jeb.02340.

Ballarin, E., Borsetto, C., and Cellini, M. 1989. Adaptation of the Conconi test to children and adolescents. Int J Sport. Med 10: 334–338.

Beattie, K., Carson, B., and Lyons, M. 2017. The effect of strength training on performance indicators in distance runners. J Strength Cond Res 31(1): 9–23.

Blagrove, R.C., Howatson, G., and Hayes, P.R. 2018. Effects of Strength Training on the Physiological Determinants of Middle- and Long-Distance Running Performance: A Systematic Review. Sport. Med. 48(5): 1117–1149. Springer International Publishing. doi:10.1007/s40279-017-0835-7.

Bodner, M.E., and Rhodes, E.C. 2000. A review of the concept of the heart rate deflection point. Sport. Med. 30(1): 31–46. doi:10.2165/00007256-200030010-00004.

Buchheit, M., Solano, R., and Millet, G.P. 2016. Heart-Rate Deflection Point and the Second Heart-Rate Variability Threshold during Running Exercise in Trained Boys. Pediatr. Exerc. Sci. 19(2): 192–204. doi:10.1123/pes.19.2.192.

Conconi, F., Ferrari, M., Ziglio, P.G., Droghetti, P., and Codecà, L. 1982a. Determination of the anaerobic threshold by a noninvasive field in man. J. Appl. Physiol. 52(4): 869–873.

Conconi, F., Ferrrari, M., Ziglio, P., Droghetti, P., and Codeca, L. 1982b. Determination of the anaerobic threshold by a noninvasive field test in runners. J. Appl. Physiol. 52: 862–873.

Czuba, M., Zając, A., Cholewa, J., Poprzęcki, S., Waśkiewicz, Z., and Mikołajec, K. 2009. Lactate Threshold (D-Max Method) and Maximal Lactate Steady State in Cyclists. J. Hum. Kinet. 21(1): 49–56. doi:10.2478/v10078-09-0006-5.

Dalleau, G., Belli, A., Bourdin, M., and Lacour, J. 1998. The spring-mass model and the energy cost of treadmill running. Eur J Appl Physiol Occup Physiol 77(3): 257–263.

Delevatti, R., Kanitz, A., Alberton, C., Pantoja, P., Marson, E., Pinho, C., Lisboa, S., Bregagnol, L., and Kruel, L. 2015. Heart rate deflection point as an alternative method to identify the anaerobic threshold in patients with type 2 diabetes. Apunt. Med. l'Esport 50(188): 123–128. doi:10.1016/j.apunts.2015.05.001.

Farrell III, J., Lantis, D., Ade, C., Cantrell, G., and Larson, R. 2018. Aerobic exercise supplemented with muscular endurance training improves onset of blood lactate accumulation. J. Strength Cond. Res. 32(5): 1376–1382.

Farrell, J., Lantis, D., Ade, C., Cantrell, G., and Larson, R. 2016. Aerobic Exercise Supplemented with Muscular Endurance Training Improves Onset of Blood Lactate Accumulation. Sport. Med. Rehabil. J. 1(1): 1–6.

Fernandes-da-Silva, J., Castagna, C., Teixeira, A.S., Carminatti, L.J., and Guglielmo, L.G.A. 2016. The peak velocity derived from the Carminatti Test is related to physical match performance in young soccer players. J. Sports Sci. 34(24): 2238–2245. doi:10.1080/02640414.2016.1209307.

Frontera, W.R., Meredith, C.N., O`Reilly, K.P., and Evans, W.J. 1990. Strenght training determinants o VO2max in older men. J Appl Physiol 68: 329–333.

Henritze, J., Weltman, A., Schurrer, R.L., and Barlow, K. 1985. Effects of training at and above the lactate threshold on the lactate threshold and maximal oxygen uptake. Eur. J. Appl. Physiol. Occup. Physiol. 54(1): 84–88. doi:10.1007/BF00426304.

Hickson, R., Dvorak, B., Gorostiaga, E., Kurosski, T., and Foster, C. 1988. Potential for strength and endurance training to amplify endurance performance. J Appl Physiol 65(5): 2285-2290.

Hofmann, P., Pokan, R., Preidler, K., Leitner, H., Szolar, D., Eber, B., and Schwaberger, G. 1994. Relationship between heart rate threshold, lactate turn point and myocardial function. Int. J. Sports Med. 15(5): 232–237. doi:10.1055/s-2007-1021052.

Hollings, M., Mavros, Y., Freeston, J., and Singh, M.F. 2017. The effect of progressive resistance training on aerobic fitness and strength in adults with coronary heart disease: A systematic review and meta-analysis of randomised controlled trials. Prev. Cardiol. 24(12): 1242–1259. doi:10.1177/2047487317713329.

Hopkins, W., Marshall, S., Batterham, A., and Hanin, J. 2009. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sport. Exerc 41(1): 3–13.

Ivy, J., Withers, R., Van Handel, P., Elger, D., and Costill, D. 1980. Muscle respiratory capacity and fibre type as determinants ofthe lactate threshold. J Appl Physiol 48: 523–527.

Kraemer, W., and Ratamess, N. 2004. Fundamentals of Resistance Training: Progression and Exercise Prescription. Med. Sci. Sports Exerc. 36(4): 674–688.

Kubo, K., Kanehisa, H., and Fukunaga, T. 2002. Effects of resistance and stretching training programmes on the viscoelastic properties of human tendon structures in vivo. J Physiol 538(1): 219–226.

Kuipers, H., Verstappen, F., Keizer, H., Geurten, P., and Van Kranenburg, G. 1985. Variability of aerobic performance in the laboratory and its physiological correlates. Int. J. Sports Med. 6: 197–201.

Lantis, D., Farrell III, J., Cantrell, G., and Larson, R. 2017. Eight Weeks of High-Volume Resistance Training Improves Onset of Blood Lactate in Trained Individuals. J. Strength an Cond. Res. 31(8): 2176–2182.

Manoel, F., da Silva, D., Lima, J., and Machado, F. 2017. Peak velocity and its time limit are as good as the velocity associated with VO2max for training prescription in runners. Sport. Med. Int. Open 01(01): E8–E15. doi:10.1055/s-0042-119951.

Mclaughlin, J., Howley, E., Bassett, J., Thompson, D., and EC., F. 2010. Test of classic model for predicting endurance running performance. Med Sci Sport. Exerc 42: 991–997.

Mikkola, J., Rusko, H., Izquierdo, M., and Gorostiaga, E.M. 2012. Neuromuscular and Cardiovascular Adaptations During Concurrent Strength and Endurance Training in Untrained Men. 21: 702–710. doi:10.1055/s-0031-1295475.

Millet, G., Jaouen, B., Borrani, F., and Candau, R. 2002. Effects of concurrent endurance and strength training on running economy and VO2 kinetics. Med Sci Sport. Exerc 34(8): 1351–1359.

Monteiro, E.R., Novaes, J.S., Fiuza, A.G., Portugal, E., Triani, F.S., Bigio, L., Santos, R., Palma, A., and Corrêa Neto, V.G. 2018. Behavior of Heart Rate Variability After 10 Repetitions Maximum Load Test for Lower Limbs. Int. J. Exerc. Sci. 11(6): 834–843. Available from http://www.ncbi.nlm.nih.gov/pubmed/29997739%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC6033492.

Moreira, S., Oliveira, R., Nakamura, F., and Campbell, C. 2010. Lactate threshold prediction by blood glucose and rating of perceived exertion in people with type 2 diabetes. Percept. Mot. Skills 111(2): 365–378.

Ratamess, N., Alvar, B., Evetoch, T., Housh, T., Kibler, W., Kraemer, W., and Triplett, N. 2009. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. Med. Sci. Sports Exerc. 41(3): 687–708. doi:10.1249/MSS.0b013e3181915670.

Siahkouhian, M., and Meamarbashi, A. 2013. Advanced methodological approach in determination of the heart rate deflection point: S.Dmax versus L.Dmax methods. J Sport. Med Phys Fit. 53(27–33).

Simão, R., Farinatti, P., Polito, M., Maior, A., and Fleck, S. 2005. Influence of exercise order on the number of repetitions performed and perceived exertion during resistance exercises. J Strength Cond Res. 19(1): 152–156.

Sjodin, B., Jacobs, I., and Svedenhag, J. 1982. Changes in onset of blood lactate accumulation(OBLA) and muscle enzymes after training at OBLA. Eur J Appl Physiol 49: 45–57.

Staron, R.S., Leonardi, M.J., Karapondo, D.L., Malicky, E.S., Falkel, J.E., Hagerman, F.C., and Hikida, R.S. 1991. Strength and skeletal muscle adaptations in heavy-resistance-trained women after detraining and retraining. J. Appl. Physiol. 70(2): 631–640. doi:10.1152/jappl.1991.70.2.631.

Vachon, J., Basset Jr, D., and Clarke, S. 1999. Validity of the heart rate deflection point as a predictor of lactate threshold during running. J. Appl. Physiol. 87(1): 452–459.