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Response of Critical Speed to Different Macrocycle Phases during Linear Periodization on Young Swimmers

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Abstract

Sport training programs to young swimmers have to aggregate different physical stimulus to collaborate with overall physical development, which can lead to reach best results in competitions. Linear periodization seems to be a powerful tool that allow the organization of these stimulus. However, this model has been not studied. Regarding physical capacities, aerobic fitness is inversely related with fatigue and exercise performance. Although aerobic capacity evaluation used to be expensive, critical speed (CS) is easy and non-expensive tool capable to make this measurement. Thus, the aim of this study was evaluate the effects of linear periodization in CS on well-trained young swimmers. Sixteen athletes (age: 14.06 ± 1.22 years, height: 163.52 ± 10.99 cm, weight: 57.4 ± 12.7 kg, body mass index: 21.24 ± 37 ; 7 ♀), were underwent to a linear macrocycle training with 23 weeks divided in four mesocycles: general endurance (i.e., 4 weeks), specific endurance (i.e., 8 weeks), competitive (i.e., 7 weeks) and taper (i.e., 4 weeks). Results showed significantly improve on CS after competitive and taper mesocycle phases, which was composed by higher training intensity in comparison with other macrocycle phases. Therefore, the results of the present study indicate a collaboration of mesocycle intensity on the cumulative effects of linear periodization in CS improve on young swimmers.

Keywords: Swimming, Linear Periodization, Critical Speed, Young Swimmers

Introduction

Training programs for young swimmers should promote improvement in physical and technical skills, collaborating to an overall development along different phases of their athletic career (Maglischo, 1999; Makarenko, 2001). For this, different kinds of exercises and stimulus (e.g. high, moderate and low intensity) should be aggregate and offer in the right time of the training program, collaborating to promoting all necessary adaptations (Bompa, 2002; Maglischo, 1999; Makarenko, 2001).

Periodization of training program is a powerful tool, which collaborate to the organization of exercise variables (e.g. volume, intensity, rest) (Brown & Greenwood, 2005; Harries, Lubans, & Callister, 2015; D. Wathen, Baechle, & Earle, 2008). Due its design, different stimulus and kinds of exercises can be offer to the athlete in the right time of physical training program, eliciting different physiological beneficial adaptations, as well as preventing overtraining, which lead to decrease on performance, mood alterations and — possibly — health problems (Brown & Greenwood, 2005; Harries, et al., 2015; D. Wathen, et al., 2008). Therefore, the periodization physical training programs allow athletes to develop their best performance, leading to the best possible results in the main competitions, but without impair their health and integrity (Bompa, 2002; Olbrecht, 2000; Weineck, 1999).

Regarding the kind of periodization, the linear periodization (LP) — which is characterized by concomitant increase on exercise intensity and decrease on exercise volume — has been demonstrated to be a better approach than non-periodized programs to cause physiological improvements (Baker, Wilson, & Carlyon, 1994; Fleck, 1999; Issurin, 2010; Rhea & Alderman, 2004; D. Wathen, et al., 2008).

In swimming, a higher aerobic capacity collaborate to athletes avoid to reach anaerobic threshold, which limit the continuation of physical exercise, lead the individual to fatigue or, at least, decrease on the intensity of the performance. Tools applied to measure aerobic capacity used to be expensive and needs to be performed by an experiment team, which may impair its applicability. Thus, in young swimmers, Critical Speed (CS) has been recommended as powerful, easy and reliable tool to predict anaerobic threshold and evaluate aerobic capacity in a non-invasive way (Franken, Diefenthaler, Carpes, & Castro, 2011; Wakayoshi et al., 1992; Wakayoshi et al., 1993).

However, few studies has been observed the effects of a periodized physical training programs on aerobic capacity on young swimmers, particularly studying CS improvement. Therefore, the aim of the present study was observed the impact of a LP physical training program on CS on young well-trained swimmers.

Material and Methods

This is an experimental study with a within-subject design.

Subjects

Sixteen well-trained young swimmers (age: 14.06 ± 1.22 years, height: 163.52 ± 10.99 cm, weight: 57.4 ± 12.7 kg, body mass index: 21.24 ± 37 ; 7 ♀) were volunteers in the present study. All athletes integrated the same team, which participate on regional and state high-level competitions. Volunteers have been underwent to daily (i.e. 6 days per week) physical training with an approximately duration of two hours and thirty minutes (i.e. ~15 hours per week), at least, during the last year. During physical training program, volunteers did not

show muscular, articular or bone injury, since all completed all experiments (i.e. exercise sessions and tests). A convenience sampling methodology was used in the present study. This study was according of guideline of resolution 196/96 of national health council. The research was approved in ethic committee of UNIMEP (protocol number 38/05) and was developed in accordance with the Declaration of Helsinki, in Resolution 196/96 of the National Health Council.

Procedures

To investigate the impact of LP in aerobic capacity on well-trained young swimmers, CS was evaluated in the end of each mesocycle (i.e., 5th, 13th, 20th, and 24th weeks). CS evaluation was realized after breakfast, between 7:00 and 10:00am, and all subjects were instructed to refrain from physical exercise for 96 hours before the test. A verbal encouragement was gave to volunteers during all tests. All volunteers were familiarized with the procedures of CS evaluation.

Linear periodization program

Physical training program after a two months holiday, in the onset of the year. LP program was characterized by one macrocycle and four mesocycles. The macrocycle was composed by 23 weeks, which was divided in specific training programs, in accord of the aim of the period: general endurance (i.e. 4 weeks; mean of swimming: ± 2.017 meters per week, low intensity aerobic exercise, technical and speed.), specific endurance (i.e. 8 weeks; mean of swimming: 23.300 ± 2.974 meters per week, with high intensity aerobic exercise, technical and speed), competitive (i.e. 7 weeks; mean of swimming: 24.770 ± 2.528 meters per week, with high intensity and high volume of anaerobic resistance exercise) and taper (i.e. 4 weeks; mean of swimming: 17.150 ± 1.077 meters specific tasks at high intensity. The training load decreased by volume, but the intensity was the same of competitive phase). Alteration on training volume showed a significantly linear trend to decrease ($P < 0.0001$) during mesocycles, as is expected to be in LP designed physical training programs. All training sessions were realized in the morning, between 7:00 and 9:00 am.

In summary, total swimming week training volume was around 24196 ± 3908 meters. Training sessions were realized six days per week, with an approximately duration of two hours and thirty minutes. Training routine consisted of specific swimming exercises, power, endurance, anaerobic resistance, and technique exercises.

The design of the macrocycle, with the percentage of training type attributed in each mesocycle can observed in figure 1.

Macrocycle																							
Meso	General				Specific endurance								Competitive						Taper				
Micro	1	2	3	4	T1	6	7	8	9	10	11	12	T2	14	15	16	17	18	19	T3	21	22	T4
Characterization of different mesocycles																							
Training		General endurance				Specific endurance								Competitive						Taper			
Aerobic		64.27%				57.85%								54.29%						38.44%			
Anaerobic		3.08%				5.16%								10.43%						14.75%			
Velocity		0.63%				4.89%								4.1%						4.85%			
Technique		7.9%				5.55%								2.3%						0.77%			
Warm up / cool down		24.1%				26.53%								28.85%						41.15%			

Figure 1. T1: Test 1; T2: Test 2; T3: Test 3; T4: Test 4; Meso: Mesocycle; Micro: Microcycle

Determination of Critical Speed

CS was determined at the end of each mesocycle phase. After a standard warm-up, the athletes performed maximal efforts of 100, 200 and 400 meters crawl swimming in distinct and consecutive days, during the control microcycle. Athletes performed sprints, starting inside the pool, beginning with an impulse in the pool wall at a measurer sign. Shots were timed by manual stopwatch and the results were written down in a spreadsheet. CS was calculated by formula that result in a straight inclination from the values of distance (m) and time (s) according Wakayoshi et al. (1993). The formula was calculate using a excel program.

Statistical Analyses

Normality of data was tested using the Kormonov-Smirnov test. After data showed a non-Gaussian distribution, *Friedmann* test was applied to verify differences between the different mycrocycles (repeated measures), and Dunns test was used as a post-hoc test to show the location of the differences, when necessary. All tests were performed in Statistical Package for Social Sciences (SPSS) 19.0 program, adopting a significant level of $P < 0.05$.

Results

Results of CS (m/s) are presenting in mean and 95 % confidence interval for mean (CI 95%) and are showing on table 1.

MG and FG showed a significantly increase on CS after competitive (T3) and taper (T4) mesocycles in comparison with general endurance (T1) mesocycle. Furthermore, CS after taper mesocycle (T4) was also significantly higher than specific endurance (T2) mesocycles. When both groups were analyzed together, significantly increase on CS was observed after competitive (T3) and taper (T4) mesocycles in comparison with general endurance (T1) and specific endurance (T2) mesocycles.

Table 1. Results of CS (m/s) on TG, MG and FG during macrocycles.

	T1	T2	T3	T4
Mean MG	1,1	1,14	1,16 a	1,17 a
CI 95%	1-1,2	1,03-1,25	1,06-1,27	1,08-1,26
Mean FG	1	1,02	1,07 a	1,08 ab
CI 95%	0,88-1,13	0,88-1,15	0,96-1,17	1-1,16
Mean TG	1,06	1,09	1,12 ab	1,13 ab
CI 95%	0,98-1,13	1-1,17	1,05-1,19	1,07-1,19

MG= Male group, FG= Female group, CI= Confidence interval, TG= Total group

a = $P < 0,05$ in relation to T1, b = $P < 0,05$ in relation to T2.

Discussion

The main results of the present study is that a LP physical training program can cause increase in CS on male, female and altogether during a macrocycle with a duration of 23 weeks. Significantly increase was observed after competitive (T3) and taper (T4) mesocycles. These periods were characterized by high intensity training programs, which had a duration of eleven weeks. Therefore, this data demonstrated the collaboration of high exercise intensity in the cumulative effects of the LP to improve CS.

CS is a low cost and easy to apply tool widely used to measure aerobic fitness and to exercise prescription on different sport modalities (Clarke, Presland, Rattray, & Pyne, 2014; Oshita et al., 2009; Toubekis, Tsami, Smilios, Douda, & Tokmakidis, 2011). CS is characterized as the swimming or running velocity that athletes can theoretically maintain over a very long period without exhaustion (Wakayoshi, et al., 1992; Wakayoshi, et al., 1993). Furthermore, CS showed high correlation with performance on Yo- Yo test, total distance traveled and average speed during a game in rugby professional players and with middle and long swimming tests in finswimming (Clarke, et al., 2014; Oshita, et al., 2009; Toubekis, et al., 2011).

Regarding swimming, pioneering works from Wakayoshi group demonstrated relation between CS and performance on swimming tests, velocity during onset blood lactate accumulation (i.e., AT), and VO₂ max in professional athletes (Wakayoshi, et al., 1992; Wakayoshi, et al., 1993). However, despite its importance, just few studies investigated progression on CS after each mesocycle during a periodization program in swimmers (Guedes, Costa, Pereira, & Silva, 2011).

Results of present study did not show significantly alterations between general endurance (T1) and specific endurance (T2) periods, which have a higher volume than competitive (T3) and taper (T4). However, on the other hand, during competitive (T3) and taper (T4) phases, characterized by increase on exercise intensity, was observed improvement on CS. One of the possible benefits of periodization is to collaborate with a sum effect of training, since improve on physiological fitness are not necessarily observed after the specific mesocycle, but can be observed during other mesocycles or just in the end of the macrocycle, ranging with periodization (I. Wathen, 2008).

However, manipulation of the variables of physical training (e.g. volume, intensity) can lead to distinct adaptations, mainly during periodization. Regarding physical training volume, Toubekis et al (2011) studied the impact of the alteration on training volume on endurance fitness on swimmers. Researchers underwent seven young swimmers to 14 weeks of specific and overall physical training and were evaluated about alterations on CS. The study was composed by a first part: 6 weeks with low swimming training volume (~129.00 m), and a second part: 7 weeks with high swimming training volume (~203.500m). Results did not show on CS after 6 and 14 weeks. Authors discourse about the possibility of alterations on training volume not be the better modulation to improve CS on young swimmers

Such as Toubekis et al (2011), in the present study high training volume — present during T1 — was not capable to cause increase on CS alone. Is possible that higher volume, which was preconized to this period, could not lead to minimal physiological stress necessary to cause beneficial adaptations on endurance fitness, since athletes in the present study were well-trained and presented a minimal of one-year experience. In fact, improve on performance are inversely related with initial performance levels (Mujika et al., 1995).

On the other hand, increase on training intensity has been suggested as a better variable of physical training to manipulate to cause improve on endurance fitness in competitive swimmers than training volume (Mujika, et al., 1995; Toubekis, et al., 2011). In the study of Mujika et al (1995), eighteen international-rank swimmers were following during a real competitive training program. During the period, researches recorded the intensity volume and frequency of the athletes, and correlated with the improve of the performance during the training period. Results demonstrated the mean of the intensity as the main factor which influence on performance in swimmers. However, researches did not observed relation between the improving on the performance and frequency or volume. Furthermore, decrease on volume during taper period was related with improve on performance.

Results from Mujika et al (1995) can corroborate to explain the results of the present study. First, during competitive phase (T3) intensity training increase ~5% in comparison with specific endurance (T2) and CS increase significantly after this phase. Second, CS demonstrated improvement after T3 and T4. These periods showed decrease on training volume (taper) in the same way that was observed in Mujika et al (1995). Maintenance of intensity during taper, with progressively decrease on training volume, can collaborate to recovery from accumulated training stress allow physiological recovery, and posterior adaptation (Mujika, Padilla, Pyne, & Busso, 2004).

Taken together, these results demonstrated a possible influence of intensity on aerobic fitness and consequently on CS. Thus, offer high intensity training during a periodization, mainly during competitive and taper phase, can collaborate with beneficial adaptations on aerobic fitness. However, despite the results about training intensity, a sum effect of all phase of periodization cannot be rule out (Pyne, Lee, & Swanwick, 2001).

The main limitations in the present study, is the lack of a control group to analyze the differences of the present study and the results from non-periodization or another kind of periodization program (e.g. undulatory).

The present study showed that a LP physical training program can lead to increase on CS in young well-trained swimmers. Furthermore, data showed a potential relation of the intensity of training period with improvements on performance, since increase on CS was only observed after high intensity microcycles.

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Conflict of Interest

The authors have not declared any conflicts of interest.

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REFERENCES

Baker D, Wilson Greg, Carlyon R (1994). Periodization: The Effect on Strength of Manipulating Volume and Intensity. *The Journal of Strength & Conditioning Research*, 8(4), 235-242.

Bompa TO (2002). Periodização. *Teoria e metodologia do treinamento. 4ª edição Guarulhos: Phorte editora.*

Brown Lee E, Greenwood M. (2005). Periodization Essentials and Innovations in Resistance Training Protocols. *National Strength and Conditioning Association*, 27(4), 80-85.

Clarke AC, Presland J, Rattray B, Pyne DB (2014). Critical velocity as a measure of aerobic fitness in women's rugby sevens. *J Sci Med Sport*, 17(1), 144-148. doi: 10.1016/j.jsams.2013.03.008

Fleck SJ (1999). Periodized Strength Training: A Critical Review. *The Journal of Strength & Conditioning Research*, 13(1), 82-89.

Franken M, Diefenthaler F, Carpes FP, Castro FAS (2011). Esforço percebido e cinemática em percentuais da velocidade crítica na natação. *Motriz: Rev. Educ. Fis*, 17(4), 708-718.

Guedes J, Costa A, Pereira R, Silva SFD (2011). Sensibilidade da velocidade crítica em jovens nadadores durante um macrociclo de treinamento. *Brazilian Journal of Biomechanics*, 5(3), 156-167.

Harries SK, Lubans DR, Callister R (2015). Systematic review and meta-analysis of linear and undulating periodized resistance training programs on muscular strength. *The Journal of Strength & Conditioning Research*, 29(4), 1113-1125.

Issurin VB (2010). New horizons for the methodology and physiology of training periodization. *Sports Med*, 40(3), 189-206. doi: 10.2165/11319770-000000000-00000

Maglischo EW (1999). *Nadando ainda mais rápido*. São Paulo: Manole.

Makarenko LP (2001). *Natação: seleção de talentos e iniciação desportiva*. Porto Alegre: Artmed Editora.

- Mujika I, Chatard JC, Busso T, Geysant A, Barale F, Lacoste L (1995). Effects of training on performance in competitive swimming. *Can J Appl Physiol*, 20(4), 395-406.
- Mujika I, Padilla S, Pyne D, Busso T (2004). Physiological changes associated with the pre-event taper in athletes. *Sports Med*, 34(13), 891-927.
- Olbrecht J (2000). *The science of winning: planning, periodizing and optimizing swim training*. Luton: Swimshop.
- Oshita K, Ross M, Koizumi K, Kashimoto S, Yano S, Takahashi K, Kawakami M (2009). The critical velocity and 1500-m surface performances in Finswimming. *Int J Sports Med*, 30(8), 598-601. doi: 10.1055/s-0029-1214378
- Pyne DB, Lee H, Swanwick KM (2001). Monitoring the lactate threshold in world-ranked swimmers. *Med Sci Sports Exerc*, 33(2), 291-297.
- Rhea MR, Alderman BL (2004). A meta-analysis of periodized versus nonperiodized strength and power training programs. *Research quarterly for exercise and sport*, 75(4), 413-422.
- Toubekis AG, Tsami AP, Smilios IG, Douda HT, Tokmakidis SP (2011). Training-induced changes on blood lactate profile and critical velocity in young swimmers. *J Strength Cond Res*, 25(6), 1563-1570. doi: 10.1519/JSC.0b013e3181ddfafc
- Wakayoshi K, Ikuta K, Yoshida T, Udo M, Moritani T, Mutoh Y, Miyashita M (1992). Determination and validity of critical velocity as an index of swimming performance in the competitive swimmer. *Eur J Appl Physiol Occup Physiol*, 64(2), 153-157.
- Wakayoshi K, Yoshida T, Udo M, Harada T, Moritani T, Mutoh Y, Miyashita M (1993). Does critical swimming velocity represent exercise intensity at maximal lactate steady state? *Eur J Appl Physiol Occup Physiol*, 66(1), 90-95.
- Wathen D, Baeckle T, Earle R (2008). Periodization. In Thomas R Baeckle & Roger W Earle (Eds.), *Essentials of strength training and conditioning* (Vol. 3): Human kinetics.
- Wathen I (2008) *Essentials of strength training and conditioning*.
- Weineck J (1999). *Treinamento ideal*. São Paulo: Manole.