The effects of ten weeks block and reverse periodization training on swimming performance and body composition of moderately trained female swimmers.

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Abstract

The aim of the present study was to analyze the change in competitive times of a 100m (t100c) front crawl swim performance and body composition values, after 10 weeks of assessing twenty moderately trained female swimmers, divided into two groups of training – Block periodization (BP) and reverse periodization (RP). The two groups performed identically in terms of volume and intensity but in different training protocols. The BP group began their training program performing aerobic training from weeks 1 to 4 and changed training to high-intensive interval training in weeks 5 to 8. The RP group began their program of high-intensive interval training from weeks 1 to 4 and changed to aerobic training from weeks 5 to 8. Both groups completed identical programs of training reduction (Taper) during weeks 9 and 10. Evaluations were made before the beginning of the program (T1), at the 4th week after the beginning of the swimming training (T2), at the 8th week (T3), and at the 10th week (T4). Results show RP decreases significantly ($p<0.05$) in t100c, after 10 weeks of training, and BP decreases significantly ($p<0.05$) in terms of body composition values. Accordingly, it is concluded that RP indicates success results in competition performance, and BP is a preferred option to improve body composition values in moderately trained female swimmers.

Introduction

Periodization of training is a process which includes variations of volume, intensity and frequency of training, in order to improve athletes' sports performances Matveyev, 1977; Rhea et al. 2003; Prestes et al. 2009). A goal of periodized programs is to optimize training in both short and long training periods (e.g., weeks, months, years). Most coaches and athletes, from beginners to elite-level performers, frequently employ periodized programs in an attempt to maximize performance, achieved through correct stress/recovery relationships.

A traditional program of periodization usually starts by building the aerobic training in a preparatory period and gradually altering the preparation by reducing volume and increasing intensity to a competitive period. This program often concludes with a tapering period of reduction volume previously to main competition as explained by Mujika, (2010). In some sports training, different models of periodization have been suggested in which training loads are concentrated in short periods of time in an attempt to increase the number of peak performances per year by following the same progression – first an aerobic training period, followed by a period of intensity. Examples of this training include the Block Training System of Verkhosansky, (1999) and Block Periodization (BP) of Issurin, (2010). Because the three periods are designated Accumulation-Transformation-Realization; this program of periodization is referred to as ATR..

Reverse Periodization (RP) introduced a paradigm that is completely opposite to the tendency of the training load programmed by traditional periodization programs. Both programs (BP and RP) often concludes with a tapering period of reduction in volume prior to the main competition (Bosquet et al. 2007; Mujika, 2010). The RP was studied in strength training, starting with high-intensity/low-volume and gradually increasing volume and reducing intensity. In fact, RP was studied in weight-training (Rhea et al. 2003; Prestes et al. 2009), but to date has been poorly studied in the swimming training context (Arroyo-Toledo and González-Ravé, 2011; Arroyo-Toledo, 2011).

Because these processes of periodization are accompanied by changes in body composition, e.g. in a recent study where included 47 untrained women of 14-19 years old, the group swam two sessions per week during 14 weeks of 45 minutes of moderated low intensity training; at the end of the study the participants reduced significantly body fat mass in over 8% while increase significantly aerobic endurance capacity (Sideraviciüte et al. 2006). In some cases anthropometric measures may be related to performance (Siders et al. 1993), but in a previous study it was concluded that lean body mass appears to influence swimming performance, while body fatness is relatively unimportant (Stager et al. 1984).

However, no previous study has been conducted, comparing the effects of these two different trends of training, block and reverse periodization in moderately trained female swimmers.

Methods

The primary purpose of this research was to compare how the organization of BP and RP, affects improvements in swimming performance in moderately trained female swimmers. The secondary purpose was to examine if changes in the volume and intensity affect body composition values.

Volume and intensity were controlled for both groups throughout the training program to avoid attributing any outcomes to the differences in periodization. Similarly, all participants received nutritional information and were required to avoid eating food supplements during the course of the study. An attempt was made to control physical activity outside of the training program.

Participants

The participants were selected in accordance with the following criteria: age between 14 to18 years old; a minimum 4 years and maximum 6 years of previous experience in swimming training and with practicing not more than three session per week before the beginning of the study; subjects also did not report any characteristics that would impede their participation in high intensity training in swimming. This provided a total of twenty female swimmers of moderately trained levels of competition (16.1±1.0 yrs 166.4±3.5 cm 57.3±5.7 kg) divided in two groups traditional periodization (BP) and reverse periodization (RP) with main objective to prepare over a 10-week period their best performance in the 100m crawl and evaluated four times during the study. Statistical analyses showed Gaussian´s distribution, and no significant baseline differences in swimming performance or body composition (Table 1). Each participant and their parents was informed of all possible risks before the investigation, and signed an informed consent document, which was approved by the Ethics Committee of Castilla-La Mancha University. All procedures were in accordance by the American College of Sports Medicine guidelines.

Table 1. Baseline subject characteristics

Variables	BP	RP
Age (y)	16.3 ± 1.1	15.6 ± 1.0
Height (cm)	166 ± 2.0	164 ± 3.6
Body mass (kg)	59.7 ± 7.1	53.4 ± 2.9
Body mass index	25.1 ± 1.8	24.5 ± 1.1
Swimming performance (s)	64.7 ± 1.3	70.5 ± 2.1

BP=block periodization group (n=10); RP= reverse periodization group (n=10). Each column shows data from the baseline evaluation of respective group. The values were expressed by mean ± standard error of mean ($p<0.05$).

Testing protocols

All subjects performed a familiarization with the various test and assessment tools, 2 days before the first test and at the beginning of the study. They participated in the following tests.

Test of Body Composition

We used a segmental multifrequency bioimpedance analyzer (InBody 720, Biospace Co. Ltd., Seoul, South Korea) to assess body composition and measurements. The "InBody 720" is a multifrequency impedance plethysmograph body composition analyzer, which takes readings from the body using an 8-point tactile electrode method, measuring resistance at 5 specific frequencies (1, 50, 250, 500 kHz, and 1 MHz) and reactance at 3 specific frequencies (5, 50, and 250 kHz) on each of 5 segments (right arm, left arm, trunk, right leg, and left leg). Participants were instructed not to do any type of physical activity for 24 hours before testing. They were also told not to eat any food for 4 hours before the analysis to maintain a good hydration status, and then 30 minutes before beginning the tests, they were asked not to drink anything, not to urinate, and or defecate. The participants stood barefoot in an upright position on foot electrodes on the instrument platform; both arms and legs were widely separated from each other. Four foot electrodes were used (2 oval-shaped electrodes and 2 heel-shaped electrodes), and participants were asked to grip the 2 palm-and-thumb electrodes (2 thumb and 2 palm electrodes per athlete). They did this barefoot and without any excess clothing. The skin and electrodes were cleaned and dried before testing. The phase of the menstrual cycle was also taken into account, and all testing were carried out during the estrogenic phase. The body height was measured using a commercial scale. We determined parameters of fat-free mass (FFM), fat mass (FM), and fat percentage (BF%). Data were electronically imported to Excel using Lookin'Body 3.0 software. The system was calibrated before each testing session. After body composition test was applied all subjects, next test was performed to obtain swimming performances data.

<u>Test of Performance</u>

The test consists in swimming 100m crawl at a maximum effort. For each test, the swimmers were required to complete a 600m warm-up and rest for between 5 to 7 minutes before commencing the test. Swimming times were recorded by three independent observers using three different chronometers (Geonaute Trt´L 900 - China). The race was also video-recorded using a digital video-camera JVC GR-D740 Japan) according to the protocol of Australian Institute of Sport (Arellano et al. 1994). Stroke rates were recorded from each swimmer using a stroke-register Pool-Mate PMO3 – China, during the race. The following data was obtained: time of 100m crawl (t100c), total strokes required to cover the distance of 100m (TS) and stroke length (SL).

Training and assessment protocols

The participants began the study following four weeks without training. Both groups performed identical volumes and intensities of training but in different periodization models. Group BP began their training program performing aerobic period (Accumulation) including low intensity training (LIT) and threshold training (ThT) during the week 1 to 4 completing 12 km per week and changing to period of intensity (Transformation); training high-intensive interval training (HIT) and (ThT) in weeks 5 to 8 to completing 7 km per week in this second meso-cycle. Group RP began their program from HIT and ThT (Intensity Period) during weeks 1 to 4 and changed training program to LIT and ThT (Aerobic Period) during weeks 5 to 8. Both groups performed identical programs of training reduction, HIT and LIT, completing 5 k per week during the weeks 9 and 10 appointed realization in case of BP and taper in RP (Figure 1).

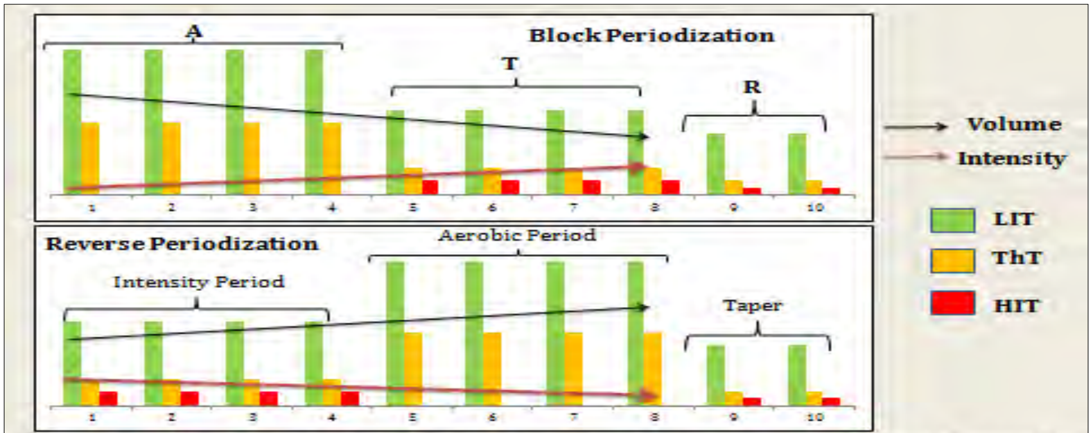

Figure 1.- Tendency of load distributions. Represents by total weekly volume in each period; A=accumulation; T=transformation; R=realization; LIT=low-intensity training; ThT= aerobic threshold training; HIT= high-intensive interval training.

Subjects trained five days per week, three sessions training the main objective of the period and two sessions performing complementary regenerative training; daily trainings expend 60 minutes or less per session. Evaluations were conducted before the beginning of the program (T1), at the 4th week after the beginning of the swimming training (T2), at the 8th week (T3) and at the 10th week (T4). Three zones of training were required to control and quantify volume and intensity of training (Laursen, 2010; Seiler, 2010), Zone 1=LIT<2 mM/l. Zone 2= ThT 3~4 mM/l. and Zone 3=HIT>4mM/l (table 2).

Table 2. Training distribution and tests.

Group	Weeks 1-4	Weeks 5-8	Weeks 9-10
BP	3/w LIT (5 x 400m) 2/w ThT (5x 200m)	3/w HIT (16x 25m) 2/w ThT (6x 200m)	3/w LIT (3 x 400m) 1/w ThT (3 x 200m) 1/w HIT (8 x25m)
	Accumulation 12km/week	Transformation 7km/week	Realization 5km/week
RP	3/w HIT (16x 25m) 2/w ThT (6x 200m)	3/w LIT (5 x 400m) 2/w ThT (5x 200m)	3/w LIT (3 x 400m) 1/w ThT (3 x 200m) 1/w HIT (8 x25m)
	Intensity period 7km/week	Aerobic period 12km/week	Taper 5km/week
Tests T1	T2	T3	T4

BP=block periodization; RP=reverse periodization; /w=sessions per week; LIT=low intensity training; ThT=threshold training; HIT=high-intensive interval training; T1=baseline valuation; T2=evaluation after 4 weeks of training; T3= evaluation after 8 weeks of training; T4=evaluation after 10 weeks of training.

Statistical analyses

Values are presented as mean ± SD. The normality of data was checked using Shapiro-wilk´s test. All variables presented normal distribution and homoscedasticity, and data was analyzed using analysis of variance (ANOVA) for repeated measures with Tukey´s post hoc test. Significance level was accepted at $p \leq 0.05$.

Results.

Results after 10 weeks of training show how RP decreased significantly ($p<0.05$) in t100c. In T2 the group RP increased significantly ($p<0.05$) in total strokes at same time than reduced significantly ($p<0.05$) stroke length. The rest of the assessment parameters of swimming performance did not change significantly in each group.

Otherwise, body composition data show how the group BP increased significantly ($p<0.05$) fat-free mass in T2 and T4, while reducing significantly ($p<0.05$) values in fat mass and body fat percentage since T2 to T4. RP group has not significantly changed in body composition values.

Table 3. Results after 10 weeks of training.

Group		BP	RP			BP	RP
Swimming performance				Body composition			
t100c (s)	T1	65.5 ± 2.2	70.5 ± 2.1	FFM (kg)	T1	26.4 ± 0.9	24.3 ± 0.5
	T2	65.2 ± 1.8	67.6 ± 1.4*		T2	27.4 ± 0.7*	24.5 ± 0.5
	T3	65.2 ± 2.0	69.9 ± 1.2		T3	26.6 ± 0.9	24.5 ± 0.5
	T4	64.7 ± 1.3	67.1 ± 1.3*		T4	27.0 ± 0.9*	24.7 ± 0.6
% change	T1-T4	↓ 1.2	↓ 5.0	% change	T1-T4	↑ 2.2	↑ 1.6
TS (ST100m)	T1	79.0 ± 2.8	94.2 ± 2.9	FM (kg)	T1	16.2 ± 2.2	10.6 ± 1.3
	T2	77.7 ± 3.9	98.7 ± 3.3*		T2	14.6 ± 1.3*	11.1 ± 1.2
	T3	77.5 ± 3.8	97.5 ± 5.2		T3	14.9 ± 1.5*	11.3 ± 1.1
	T4	77.0 ± 4.0	97.5 ± 3.0		T4	14.2 ± 1.8*	10.8 ± 1.2
% change	T1-T4	↓ 2.5	↑ 3.5	% change	T1-T4	↓ 14.0	↑ 1.8
SL (m/stroke)	T1	1.20 ± 0.04	1.02 ± 0.02	BF%	T1	28.4 ± 0.5	19.2 ± 1.9
	T2	1.27 ± 0.07	0.95 ± 0.02*		T2	22.7 ± 2.2*	19.8 ± 1.7
	T3	1.27 ± 0.07	0.97 ± 0.04		T3	26.0 ± 1.4*	20.1 ± 1.6
	T4	1.27 ± 0.08	0.97 ± 0.02		T4	25.1 ± 2.4*	19.2 ± 1.7
% change	T1-T4	↑ 5.8	↓ 5.1	% change	T1-T4	↓ 13.1	=

*=p<0.05 vs T1. BP=block periodization; RP=reverse periodization; t100c=time 100m crawl (s); TS=total strokes; SL=stroke length (m/stroke); FFM=fat-free mass (kg); FM=fat mass (kg); BF%=body fat percentage (%); T1=baseline valuation; T2=evaluation after 4 weeks of training; T3=evaluation after 8 weeks of training; T4=evaluation after 10 weeks of training. The values were expressed by mean ± standard error of the mean.

Discussion

The aim of this research was to compare how the organization of BP and RP, affect improvements in swimming performance in moderately trained female swimmers after 10 weeks of training. The results obtained show how different distributions of volume and intensity of training caused different effects in swimming performances (100m crawl) and in body composition. To our knowledge this is the first study to compare BP and RP in swimming training. Similar to previous studies in fitness and strength training (Rhea et al. 2003; Prestes et al. 2009), the present study confirms the different effectiveness of these two models of periodization – RP to improve performance and BP to improve body composition values.

Performance in 100m crawl

During the study, the groups included in this investigation did not receive information as to the values obtained in each test, except their personal times over 100m. This was done in order to avoid involuntary alterations in swimming technique. Analyzing data on the performance of swimmers in t100c between T1 to T4, we can see how the RP reduced significantly ($p<0.05$) 5.0% of the time to complete this distance. The BP reduced, 1.2% time, to perform above baseline values. The results in t100c and stroke variables show that at the end of the study results for both groups were highly influenced by the first period of training.

The BP started their program with aerobic training. The most important improvements derived from aerobic training combined low intensity with threshold training appeared at weeks four to six after increasing training volume (Ryan et al. 1990); these improvements are evident in the economy of movement (length per stroke) coinciding with aerobic threshold considered between 2~4mM/l, with limited recruitment of fast twitch muscles fibers (Maglischo, 2011), but frequently traditional training programs based in aerobic volume training, spending between 6 to 11 months per year show no significant improvements in time of competition (Kame et al. 1990; Ryan et al. 1990; Costill et al. 1991; Wakayoshi et al. 1993).

The RP initiated the study from the High-intensive interval training, this kind of work-load is the recommended training for improving the two aerobic and anaerobic metabolic functions as well as muscle buffering capacity and lactate tolerance, including as explained by Maglischo (Maglischo, 2011). Previous studies coinciding with this research demonstrated that high-intensive interval training can be trained at the beginning of a cycle preparation and the assimilation occurs in less time than the aerobic period of volume of training (Faude et al. 2008; Sperlich et al. 2010).

From high intensity interval training, the first stage of adaptation is a neural reorganization of physical resources, which translates into improvements in speed movement in the training activity. This “reorganization” is represented in the brain and muscle fibers as a new pattern of movement. Some studies explain how these improvements come from adaptations of the nervous system during speed-strength training similar than high-intensive interval training. These improvements occurring in both, transmission from the central nervous system and responses such as a reflex-type level of the spinal cord with an increase of an agonist muscle activation and antagonist muscle relaxation (Abernethy, 2005; Maglischo, 2011) these may explain the increases in the total number of strokes and provide an option to train and maintain optimal stroke frequency at the end of races, especially required in sprint races 200m and less (Arellano et al. 1994; Termin and Pendergast, 2000).

Elite swimming races of 200m and less, are completed in less than two minutes, nevertheless traditional programs expend 12 or 18 hours per week swimming excessive training volumes, with more than 75% of this volume expended under the lactic and aerobic threshold (Laursen, 2010; Seiler, 2010). Some experts believe that, this low intensity training is the main weakness that causes extreme stroke rate reductions (Costill et al. 1991; Arellano et al. 1994; Termin and Pendergast, 2000). Recent studies have shown similar results to this study where training based on large volumes of work are not profitable when compared to high- intensity training programs (Faude et al. 2008; Sperlich et al. 2010).

One of the objectives of the aerobic training is to improve the swim-efficiency index. Another is the reduction of lactate concentrations and also induce lactate clearance (Kame et al. 1990; Ryan et al.1990; Costill et al. 1991; Wakayoshi et al. 1993); hence we hypothesized that a better strategy of training sprinters relative trained level of competition, would be to perform sprint sets for the production of lactate before the aerobic threshold sets (Arroyo-Toledo and González-Ravé, 2011; Arroyo-Toledo, 2011), in order to improve the muscle buffering capacity and lactate tolerance maintaining at same time the swim-efficiency index.

Total strokes and stroke length

The BP start program during this time improved stroke length, when the group performed intensity training and taper periods; stroke values were changed but not significantly increasing the total number of strokes. The low intensity training featuring slow strokes proved very useful to the economy of swimming for long distances, but some studies support the idea of this is one of the main weaknesses for competitive swimming distances of 200m and less (Costill et al. 1991; Arellano et al. 1994; Termin and Pendergast, 2000). We confirm in the present study this group improved stroke values during the intense period of training and taper period, but not significantly.

The RP group began its program by increasing the total of strokes (4.7%), during this period and decreasing stroke length (7.3%) modifying significantly ($p<0.05$) both values – that means this group decreased its efficiency index in T2; in the second period of training, when the period increased in volume and after the Taper period, this group improved its swim-efficiency index with a non-significant improvement in the frequency of strokes. The effect showed an important but not significant difference between groups in stroke length.

Studies in high-performance swimming demonstrate a high need of stroke frequency and for maintaining high efficiency, especially at the end of sprint races (Costill et al. 1991; Arellano et al. 1994; Termin and Pendergast, 2000). Comparing the results obtained in this research with previous investigations based in high-intensity interval training, the 5.0% improvement of RP for t100c is higher than the results achieved in the cited studies, e.g. 3.4% obtained by Toussaint and Vervoorn (1990) for the same training period (10 weeks). These figures were also higher than the 2% observed in the first of the four years of a study prepared by Termin and Pendergast (2000), using high level swimmers. In all cases, the improvements obtained in this research are more than the (2~4%) improvements suggested by Laursen, (2010). But all these reports were performed employing traditional training, which means high-intensive interval training after aerobic periods of training; also an important finding of the present research is that: improvements in t100c (between T1 to T2 is 4.2% and between T3 to T4 is 4.1%) are very similar in both periods when High-intensive interval training where concluded in the periodization program, and coinciding with the 4% of the notes of Laursen (2010). We believe that these extraordinary improvements may be due to the inclusion of high-intensive interval training, the best adaptations occurring during the first period of the program when the subjects were not fatigued. This was different from the BP group, who followed high-intensive interval training after having been under stress in the aerobic period.

Moreover, these high improvements can be attributed to the lack of experience of the participants, coinciding these results with Ebben et al. (2004) who demonstrated how a similar type of training than reverse periodization (reverse step load) is a better option for improving sport performance in relatively untrained athletes.

<u>Taper period</u>

The results between T3 and T4 during the taper in the two groups were similar to the results reported by Rinehardt et al. (2000). Our BP results also coincide with Hopper et al. (1998) i.e. swimmers in both studies improved their distance per stroke with no significant post-reduction differences of workload when tested for the 100m front crawl. The results obtained during the taper represent considerably less than the 2~3% improvement obtained in different sports, triathlon, running and swimming compared to the data in the meta-analysis prepared by Bosquet et al. (2007). However, most of these results are registered in endurance races (over 10 minutes) and involve high training volumes for long distance competitions. In our study training volumes are adapted for a sprint race of approximately 1 minute, using moderately trained female swimmers.

Most of swimming training programs based on a high volume of work-load expect improvements after the taper period, Our study, and previous studies, show that aerobic volume of training does not always result in improved competitive performances after reducing the workload period (Hopper et al. 1998; Rinehardt et al. 2000; Bosquet et al. 2007).

Body composition
After 10 weeks of swimming training, the BP group obtained better results in all parameters of body composition. In this group the greatest decrease in fat mass and body fat percentage may be due primarily to the high values compared to the baseline. Despite this distribution of work-load where the first period focused on aerobic training, following the second one which was focused in intensity training, this protocol appeared to be more effective in reducing fat mass in young swimmers than the distribution model proposed in the RP. Values obtained in fat reduction of the BP group in this study are highest (14.0 vs 8.4%) than the data presented by Sideraviciüte et al. (2006). This could be attributed to the inclusion of high-intensity interval training in this group (BP) and to training five sessions per week. This was different to the study by Sideraviciüte et al. (2006) who trained two times per week, at a moderated aerobic training pace.

In fat-free mass values, both methods have similar final results, although the BP produces a higher percentage gain than the RP (2.2% vs 1.6%), somewhat similar to the study by Prestes et al. (2009) who showed that traditional periodization of training is a better option than reverse periodization to improve body composition values. It must be noted that neither of the two groups studied obtained higher results (7.8%) in fat-free mass outcomes compared to that reported in Prestes' study. This was probably due to differences of fitness activity. In swimming, the highest values in fat-free mass combined with high reduction of fat mass affect negatively effect buoyancy in the water and consequently, swimming performance. In comparison, swimmers with high values of fat mass have acceptable performance in competitions, (Stager et al. 1984; Siders et al. 1993). Therefore we suggest training for lean muscle mass gain instead of training for reducing fat mass values. According to these results, the BP model is more effective than RP to perform body composition parameters, increase fat-free mass and decrease in body fat mass to the greatest possible extent.

Limitations of the study
One weakness of our study was the limited experience level of the participants and the short period of the study. However, we believe that this study provides an important basis for understanding the effects of these two training protocols, making it possible for future studies using more swimmers that compete at a higher competitive level.

Conclusion

From the results obtained in this research, we recommend reverse periodization for swimmers at moderately trained levels of competition, if the allowed training periods are short, around ten weeks. For the researchers, it is advisable to make further studies at different levels and distances in competition to confirm the effectiveness of these two programs of periodization in swimming.

References

1. Abernethy, B. *The biophysical foundations of human movement*. Champaign, IL: Human Kinetics. 2005.

2. Arellano, R., P, Brown, J. Cappaert, and R. Nelson. Analysis of 50m, 100m and 200m freestyle swimmers at the 1992 Olympic Games. *J. Appl. Biomechs*. 10: 189-199, 1994.

3. Arroyo-Toledo, J.J. and González-Ravé J.M. Eficacia de los modelos de periodización tradicional y periodización inversa en la natación de velocidad. *NSW.* 34(4):18-23, 2011.

4. Arroyo-Toledo, J.J. Comparación de dos modelos de periodización (tradicional e inversa) sobre el rendimiento en la natación de velocidad (Doctoral Dissertation). Toledo: University of Castilla-La Mancha. 2011.

5. Bosquet, L., J. Montpetit, D. Arvisais, and I. Mujika. Effects of tapering on performance: a meta-analysis. *Med. Sci. Sports Exerc*. 39:1358-1365, 2007.

6. Costill, D. L., R. Thomas, R.A. Robergs, D. Pascoe, C. Lambert, S. Barr, and W.J. Fink. Adaptations to swimming training: influence of training volume. *Med. Sci. Sports Exerc.* 23:371-377, 1991.

7. Ebben, W., A. Kindler, K. Chirdon, N. Jenkins, A. Polichnowski, and A.V. Ng. The effect of high-load vs. high-repetition training on endurance performance. *J. Strength Cond. Res.* 18:513–7, 2004.

8. Faude, O., T. Meyer, J. Scharhaq, F. Weins, A.. Urhausen, and W. Kindermann. Volume vs. intensity in the training of competitive swimmers. *Int. J. Sports Med.* 11:906-12. 17, 2008.

9. Hooper, S. L., L.T. Mackinnon, and E.M. Ginn. Effects of three tapering techniques on the performance, forces and psychometric measures of competitive swimmers. *Eur. J. Appl. Physiol.* 78: 258-263, 1998.

10. Issurin, V. New Horizons for the Methodology and physiology of Training Periodization: Review. *Sports Med*. 40 (3): 189-206, 2010.

11. Kame, V. D., D. R. Pendergast, and B. Termin. Physiologic responses to high intensity training in competitive university swimmers. *J. Swimm. Res.* 6(4): 5-8, 1990.

12. Laursen, P. Training for intense exercise performance: high-intensity or high-volume training? *Scand. J. Med. Sci. Sports.* 20 Suppl 2:1-10, 2010.

13. Maglischo E. W. Training Fast Twitch Muscle Fibers: Why and how part I. *J. Swimm. Res.* 18:1-16, 2011.

14. Matveyev, L. *Fundamentals of Sport Training*. Moscow, Russia: Fizkultura I Sport. 1977.

15. Mujika, I. Intense training: the key to optimal performance before and during the taper. *Scand. J. Med. Sci. Sports.* 2:24-31, 2010.

16. Prestes, J., C. De Lima, A.B. Frollini, F.F. Donatto, and M. Conte. Comparison of linear and reverse linear periodization effects on maximal strength and body composition. *J. Strength Cond. Res.* 23(1): 266–274, 2009.

17. Rhea, M. R., S. Ball, W.T. Phillips, and L.N. Burkett. A comparison of linear and daily undulating periodized programs with equated volume and intensity for local muscular endurance. *J. Strength Cond. Res.* 17(1): 82-87, 2003.

18. Rinehardt, K., R. Axtell, C. Fontana, R. Breault, J. Genthe, and R. Garay. Effect of taper training in collegiate swimmers. *Med. Sci. Sports Exerc. 32(5),* Supplement abstract 975, 2000.

19. Ryan, R., E. Cotle, and R. Quick. Blood lactate profile throughout a training season in elite female swimmers. *J. Swim Res.* 6:5-9, 1990.

20. Seiler, S. What is Best Practice for Training Intensity and Duration Distribution in Endurance Athletes? *Int J. Sports Physiol. Perform.* 5:276-291, 2010.

21. Sideraviciüte, S., A. Gailiūniene, K. Visagurskiene, and D. Vizbaraite. The effect of long-term swimming program on body composition, aerobic capacity and blood lipids in 14-19-year aged healthy girls and girls with type 1 diabetes mellitus. *Med. (Kaunas).* 42(8):661-6, 2006.

22. Siders, WA., HC. Lukaski, and WW. Bolonchuk. Relationships among swimming performance, body composition and somatotype in competitive collegiate swimmers. The J of Sports Med & Physical Fitness. 33, 166-171, 1993.

23. Stager, JM., L. Cordain, and TJ. Becker. Relationship of body composition to swimming performance in female swimmers. J of Swimm Res. 1:1, 21-28, 1984.

24. Sperlich, B., M. Haegele, I. Heilemann, C. Zinner, M. De Marees, S. Achtzen, and J. Mester. High-intensity interval training improves VO_{2peak}, maximal lactate

accumulation, time trial and competition performance in 9–11-year-old swimmers. *Eur. J. Appl. Physiol.* 110(5): 1029–1036, 2010.

25. Termin, B. and D.R. Pendergast. Training using the stroke frequency-velocity relationship to combine biomechanical and metabolic paradigms. *J. Swim. Res.* 14:9-17, 2000.

26. Toussaint, H. M. and K. Vervoorn. Effects of specific high resistance training in the water on competitive swimmers. *Int. J. Sports Med.* 11:228-23, 1990.

27. Verkhosansky, Y. The end of "periodization" of training in top-class sport. *NSA*. 14(2):47-55, 1999.

28. Wakayoshi, K., T. Yoshida, Y. Ikuta, Y. Mutoh, and M. Miyashita. Adaptations to six months of aerobic swim training. Changes in velocity, stroke rate, stroke length and blood lactate. *Int. J. Sports Med*. 14(7):368-372, 1993.