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Robin Pla, Yann Le Meur, Anaël Aubry, Jean-François Toussaint, Philippe Hellard. Effects of a 6-Week Period of Polarized or Threshold Training on Performance and Fatigue in Elite Swimmers. *International Journal of Sports Physiology and Performance*, 2019, 14 (2), pp.183-189. 10.1123/ijsp.2018-0179 . hal-02936224

HAL Id: hal-02936224

<https://insep.hal.science/hal-02936224v1>

Submitted on 11 Sep 2020

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Note. This article will be published in a forthcoming issue of the *International Journal of Sports Physiology and Performance*. The article appears here in its accepted, peer-reviewed form, as it was provided by the submitting author. It has not been copyedited, proofread, or formatted by the publisher.

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Journal: *International Journal of Sports Physiology and Performance*

Acceptance Date: June 23, 2018

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DOI: <https://doi.org/10.1123/ijsp.2018-0179>

Original Investigation

Effects of a 6-week period of polarized or threshold training on performance and fatigue in elite swimmers

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Preferred running head: Training intensity distribution in swimmers

Abstract: 250 words

Content: 3039 words

Number of figures and tables: 6 (4 tables and 2 figures)

a face mask (Hans Rudolph, Inc., USA). As soon as the swimmer’s head was out of the water, the mask was put on the swimmer for 30 s. The first 20 sec were used for the analysis to determine $\dot{V}O_2$.¹⁷

Incremental test until exhaustion

The incremental test was conducted two hours after the 100 m performance. The active swimming recovery between tests was controlled for each swimmer (600 m light aerobic swimming for active recovery before ~75 min of passive recovery). The swimmers performed an incremental test in crawl to determine the speed corresponding to 4 mmol·L⁻¹ ($V_{4\text{mmol}\cdot\text{L}^{-1}}$).³ This test consisted of swimming 5 x 200 m with final 200 m swum at maximal effort, with increments of 0.05 m·s⁻¹ and 1 min of rest between each 200 m stage. Every 200 m, capillary samples for blood lactate [La]_b were collected with the same method described before.

Well-being and sleep assessment

The swimmers completed a short wellness questionnaire, as described by Noon,¹⁸ every morning before breakfast for the 6 weeks of intervention. We monitored their perceptions of well-being on seven items: motivation to train, quality of the previous night’s sleep, perceived recovery, appetite, perceived fatigue, stress and muscle soreness. To facilitate data collection in the cohort of young swimmers, we asked them to download a cell phone application and practice moving the cursor on a scale of 1 to 100. The best perception for each item was 100 and the worst perception was 1. This questionnaire was chosen because pilot trials indicated it to be practical for the swimmers to use every morning of the study. This technique was tried by the swimmers during the entire month prior to the first pre-test.

Statistical analyses

Data were analyzed using magnitude-based inferences.¹⁹ All data were log transformed before analysis to reduce bias arising from non-uniformity of error. The magnitude of the percentage change in time was interpreted by using values of the typical variation (coefficient of variation, CV) between the two pre-tests as 1.6%, with values of 0.5% (small), 1.4% (moderate), 2.6% (large), 4.0% (very large) and 6.4% (extremely large) established as criterion differences in the change in performance time between tests.²⁰ For all the other parameters, the smallest worthwhile change (SWC) was defined as a small standardized effect based on Cohen’s effect size (ES) principle (0.2 x between-athlete standard deviation).²¹ Threshold values for ES statistics were ≤ 0.2 (trivial), > 0.2 (small), > 0.6 (moderate), > 1.2 (large), > 2.0 (very large), and > 4.0 (extremely large).¹⁹ Quantitative chances of higher or lower differences were evaluated qualitatively as follows: $< 1\%$, almost certainly not; 1%–5%, very unlikely; 5%–25%, unlikely; 25%–75%, possible; 75%–95%, likely; 95%–99%, very likely; and $> 99\%$, almost certain. If the chance of having positive/beneficial or negative/harmful performances were both $> 5\%$, the true difference was assessed as unclear.

Results

Polarized versus threshold training

The total volume in kilometers and the training load were similar between POL and THR training (Table 2). The intensity distribution was 81/4/15 for POL and 65/25/10 for THR with substantially more training undertaken in zone 2 for the THR group (large effect size).

A likely small increase in performance was observed in POL ($0.97\% \pm 1.02\%$; mean \pm 90% confidence limits), while the change in performance in THR was unclear ($0.09\% \pm 0.94\%$) (Figure

2). The improvement in performance was possibly higher after POL training than THR training (0.89 ± 1.31 %, small). There was no substantial effect of gender.

The changes observed for $[La]_{max}$ were unclear for POL ($12.4 \pm 4.2\%$ vs. $12.9 \pm 3.7\%$ mmol·L⁻¹, within-group change $\pm 90\%$ CL at pre- and post-, respectively) and THR ($11.8 \pm 3.6\%$ vs. $12.5 \pm 3.6\%$, at pre- and post-, respectively) (Table 3). No clear difference in the change in $[La]_{max}$ was evident between POL and THR ($2.0 \pm 14.4\%$). We observed a possibly small larger improvement with THR for $V_{4mmol \cdot L^{-1}}$ ($0.7 \pm 1.6\%$) and $\dot{V}O_2$ ($5.8 \pm 9.8\%$), whereas the results were unclear with POL.

The self-reported swimmer well-being indices are shown in Table 4. The main finding is that swimmers undertaking POL training reported that recovery was likely to very likely better than in THR training in the final three weeks of the 6-week training intervention. No clear difference was observed for the other well-being indices.

Discussion

In this study, we expected that POL would be associated with faster performances, greater physiological adaptations and less fatigue. We observed larger improvements in swimming performance after polarized training for 6 weeks compared with threshold training. However we observed no additional physiological adaptations with POL training. Self-reported well-being indices were better for POL than for THR in the final weeks of the training period.

The physiological and performance responses to the two training models were compared with an incremental test of 5 x 200 m and a maximal test of 100 m performed as a swimming time-trial. The small beneficial effect of POL on performance improvement confirms the effectiveness of this training approach in elite swimmers. These results are in accordance with the results of earlier studies in triathlon,⁸ cycling⁷ and rowing,⁹ where most of the athletes who progressed

trained in POL. But as opposed to the other studies, the improvements in swimming performance were not associated with physiological adaptations. These studies reported improvements in $\dot{V}O_{2\max}$ after POL training,^{9,10,13,14} in $V_4\text{mmol}\cdot\text{L}^{-1}$,^{7,9,13,14} whereas we observed no clear differences in our study. Six weeks of polarized training with an 81/4/15% distribution yielded an 1% improvement in performance compared with threshold training, without a change in physiological capacities.

To our knowledge, this study is the first to systematically compare indices of well-being and recovery in polarized and threshold training. The indices were higher in the swimmers who trained in POL. For the THR group, the quality of recovery decreased until the fifth training week and self-reported feelings of fatigue were higher than in POL group. Perceived fatigue generally increases during periods of overload training and has been described as an index of an overreaching state.²² An increase in fatigue is also correlated with overload training without overexertion.²³ Chatard²⁴ used a short fatigue questionnaire with swimmers and showed that fatigue scores were strongly correlated with differences in performance and training load – the swimmers with the highest fatigue scores had the lowest performances. In our study, the swimmers in the THR group may have accumulated too much fatigue to improve their performance, whereas in the POL group most of the swimmers who improved their performance did so with less fatigue. This pattern of responses supports the contention that polarized training is less fatiguing.

The performance improvement in POL was accompanied by more time spent in race pace training compared with THR (15% vs 9%). A recent study also highlighted the importance of training at or around race pace intensities.²⁵ Pacing strategies may underpin the benefits of various intensity distribution models in complement to the physiological adaptations. A training regime incorporating a large proportion in high-velocity pace swimming seems to shift the stroke rate-

effects of the two models more marked. In the present study, polarized training modality induced substantial changes in the patterns of load, volume and intensity with regard to the usual training routines. This variability in training should therefore be established as one of the factors of progress.²⁹ Our study tested a model of endurance training in swimmers who were mainly 100 to 200 m freestyle and form stroke swimmers using a short endurance test (5 x 200 m). Future research should experimentally test this model in middle-distance, medley and distance swimmers (400 to 1500 m). An additional limitation of this study is that we did not present and compare the technical and kinematic responses induced by the two training distributions. Indeed, other studies in swimming^{26,30} have suggested that these adaptations are strongly related to the energetic characteristics and swimming speeds used during training.

Practical applications

The results of this study should help coaches to gain a sharper understanding of how the training load components (load increase, intensity distribution, period duration, taper) interact to improve performance. Polarized training may be a good option for sprinters as this type of training, when implemented appropriately (progressive load increases, sufficient macrocycle duration, and a well-conducted taper), should yield improvements in competition performance.

Conclusions

The current study is the first systematic evaluation of the effects of polarized training versus threshold training on swimmers' energetics, perceptions of fatigue and recovery, and time-trial performance. Only a small positive improvement on 100 m performance was observed for the swimmers who trained with POL compared with those who trained with THR. The performance improvements with the polarized modality may relate to a greater proportion of the training at the race pace, which is physiologically and technically a more specific type of training. The swimmers

with polarized training also reported less fatigue. For the swimmers who trained in the threshold mode, additional fatigue may have been induced by the cumulative impacts of threshold and high-intensity training. Swimmers should be monitored closely during periods of increased training loads.

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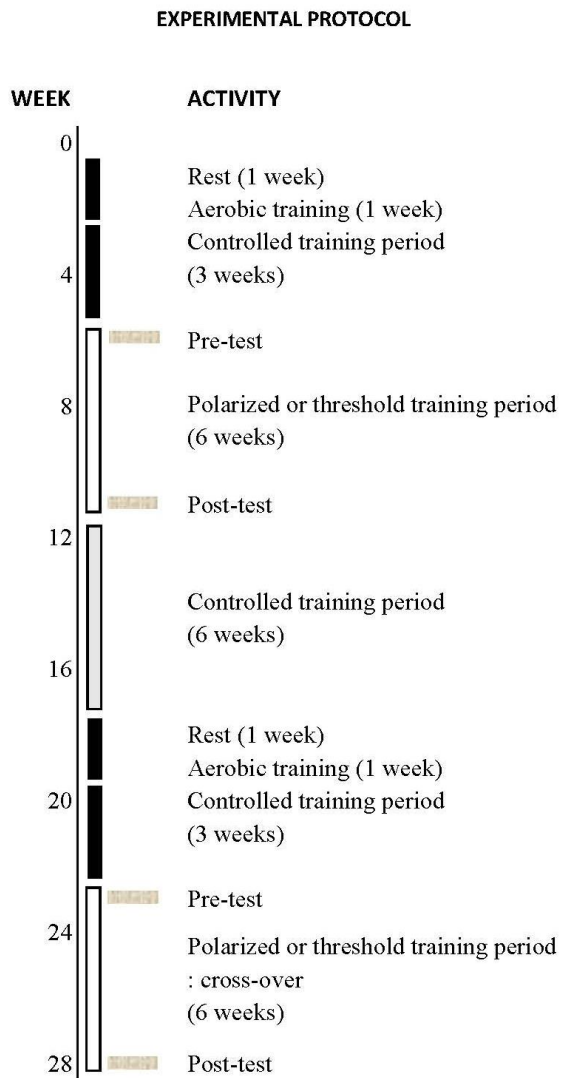


Figure 1. Study design schematic detailing the timeline for each period of the study including the testing weeks.

Table 1: Baseline characteristics of 22 elite swimmers. Mean \pm SD.

Variables	Males (n=12)	Females (n=10)
Age (years)	17 \pm 3	17 \pm 3
Body height (cm)	178 \pm 10	170 \pm 6
Body Mass (kg)	64 \pm 9	59 \pm 9
BMI	20.2 \pm 1.4	20.5 \pm 2.4
Training experience (years)	8 \pm 2	8 \pm 2
FINA points	485 \pm 92	498 \pm 75

Table 2: Total training volume completed during baseline training and six weeks of polarized and threshold training. Mean \pm SD

	Units	Base	POL	THR
Total Training Volume	Kilometers per week	37 \pm 3	42 \pm 4	42 \pm 4
Volume in Zone 1	% of training volume	70 \pm 6	81 \pm 3	66 \pm 5*
Volume in Zone 2	% of training volume	20 \pm 4	4 \pm 1	25 \pm 2*
Volume in Zone 3	% of training volume	10 \pm 2	15 \pm 2	9 \pm 3*

Abbreviations: Base, 3 weeks period before training intervention; POL, polarized training; THR, threshold training.

*Substantial differences between POL vs THR

