CHANGES IN AEROBIC AND ANAEROBIC PERFORMANCE CAPABILITIES FOLLOWING DIFFERENT INTERVAL-TRAINING PROGRAMS

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Abstract The aim of the study was to compare the effect of an increasing-distance interval-training program and a decreasing-distance interval-training program, matched for total distance, on aerobic and anaerobic performance capabilities. Forty physical education students were randomly assigned to either increasing- or decreasing-distance interval-training group (ITG and DTG), and completed two similar sets of tests before and after six weeks of training. One training program consisted of 100 – 200 – 300 – 400 – 500 m running intervals, and the other 500 – 400 – 300 – 200 – 100 m. While both training programs led to a significant improvement in 2,000 m run (ES = 0.02–0.68), the improvement in the DTG was significantly greater than in the ITG (18.3 ±3.6 vs. 12.2 ±3.2%, $p < 0.05$). In addition, while both training programs led to a significant improvement in 300 m run (ES = 0.25–0.73), the improvement in the DTG was significantly greater than in the ITG (21.1 ±1.8 vs. 15.4 ±1.1%, $p < 0.05$). The findings indicate that beyond the significant positive effects of both training programs, the DTG showed significant superiority over the ITG in improving aerobic and anaerobic performance capabilities. Athletes should acknowledge that, in spite of identical total work, interval-training program might induce different physiological impacts if order of intervals is different.

Key words performance capabilities, training programs, interval training

Introduction

Interval-training is based on the premise that an intense activity can be performed if interspersed with periods of rest. Accordingly, an individual performs the activity at a relatively high intensity, for a number of repetitions, with appropriate recovery periods between repetitions. A major advantage of this training method, and a key reason for its popularity among athletes, is its ability to improve aerobic and anaerobic capabilities simultaneously (Billat, 2001; Hazell, MacPherson, Gravelle, Lemon, 2010; Meckel, Gefen, Nemet, Eliakim, 2012). This is possible due to the significant load put on the neuromuscular and cardiovascular systems in a typical interval-training session (Loursen, Jenkins, 2002; Rakobowchuk et al., 2008; Rodas, Ventura, Cadefau, Cussó, Parra, 2000). The specific training variables – distance, intensity, and rest time between intervals – are determined according to the athletes' event specialty and physiological requirements. An aerobic-type athlete usually performs a relatively low-intensity high-volume training protocol, whereas an anaerobic-type athlete usually performs a low-volume high-intensity training protocol (Billat, 2001; Loursen, Jenkins, 2002; MacDougall et al., 1998). Usually, the different variables in interval-training are constant throughout a single session. However, coaches sometimes deviate from this norm, creating incremental protocols. For example, "increasing-interval protocol" may include increasing running distance intervals in a *single* session. Conversely, a "decreasing-interval protocol" may include decreasing running distance intervals in a *single* session. Although the total work in both protocols may be similar, the physiological stress may vary between the two due to the different running order. Indeed, it was previously shown that the mean physiological responses (i.e. heart rate and blood lactate concentration) in a single decreasing protocol were significantly higher than in a single increasing protocol, although the total work was equal (Meckel, Grodjinovsky Ben-Sira, Rotstein, Sagiv, 1997). In line with that, it was found that growth hormone (GH) concentration was significantly higher during decreasing-distance compared to increasing-distance protocol (Meckel et al., 2011). It was speculated that these differences resulted from a higher physiological stress following the first long interval in the decreasing-distance protocol, compared with the low stress following the first short interval in the increasing-distance protocol. Most recently, in a relevant intervention study, it was found that 12 training sessions of decreasing order intervals improved maximal oxygen consumption (VO_2 max) and anaerobic indices (Peak power – PP, Mean power – MP and Fatigue index – FI) significantly more than 12 sessions of increasing order intervals (Sindiani, Eliakim, Segev, Meckel, 2017).

So far, only one study compared the influence of increasing and decreasing distances interval-training programs. This study used conventional laboratory procedures to identify aerobic and anaerobic physiological changes following the two training protocols. However, the question remains whether such differences in interval order apply to aerobic and anaerobic performance capabilities in the field. The aim of the present study, therefore, was to compare the effect of increasing- and a decreasing-distance interval-training program, matched for total distance, and rest periods on aerobic and anaerobic performance capabilities in the field. Given the higher physiological responses that were found following a single decreasing compared to a single increasing-interval protocol and the higher VO_2 max and anaerobic indices that were found following the decreasing-distance interval-training program, we hypothesized that the decreasing-distance program will lead to greater improvement in field aerobic and anaerobic performance capabilities.

Methods

Participants

Forty healthy young (age 22–25) physical education students volunteered to participate in the study. The participants general fitness status was some-what higher than average for their age group, as they were routinely active in practical classes (soccer, basketball, swimming etc.) required for their academic program (Table 1). The participants performed an average of about 8 hours of physical activity every week, mostly playing ball games and some aerobic work. Standard calibrated scales and stadiometers were used to determine height and body mass. Skinfold measurement at four sites (triceps, biceps, sub-scapular and supra-iliac) was used to calculate percent body fat using standard equations. The Institutional Review Board of the Hillel-Yafe Medical

Center approved the study. The participants were informed of the experimental procedures and risks and signed an informed consent prior to the investigation.

Training Procedure

Participants were randomly assigned to one of two interval training groups – an increasing training group (ITG, n = 20) and a decreasing training group (DTG, n = 20) – after matching for aerobic (2,000 m running times) and anaerobic (100 m sprint times) scores. A week after the completion of the pre-training set of testing, each group started a-six weeks, twice a week (non-consecutive days), training program. Participants maintained their other usual weekly routine with minor changes to balance total physical activity between groups. At the end of the six weeks, participants performed a second – post-training – set of testing to evaluate training effects and fitness improvement.

Throughout each session of the six weeks interval training program, both groups performed the same work matched by total volume, intensity and recovery times. However, while one group performed an increased interval protocol in which running distances were increased by 100 m in each interval, the other group performed a decreased protocol in which running distances were decreased by 100 m in each interval throughout the training session. Specifically, the ITG performed an increased running distances starting from 100 m in the first interval and then increased by a 100 m in each interval (100 – 200 – 300 – 400 and 500 m) until 500 m in the last interval. In contrast, the DTG performed a decreased running distances starting from 500 m in the first interval and then decreased by a 100 m in each interval (500 – 400 – 300 – 200 – 100 m) until 100 m in the last interval. Resting times between intervals were increased from 3 to 9 min in the increased protocol, and decreased from 9 to 3 min in the decreased protocol. Running speed in each interval was performed at 75% of each participant 100 m best running time. Overall, the two training groups performed the same total volume of work (1,500 m) and were given the same total recovery time (24 min) in each session over the 6 weeks of training. A description of the two interval training programs, including work and rest periods, is presented in Figure 1. Participants performed an active recovery between runs (walking at a comfortable pace). In order to get familiar with the necessary running paces, participants practice two special “pace sessions” before the beginning of the program. All training sessions were performed on

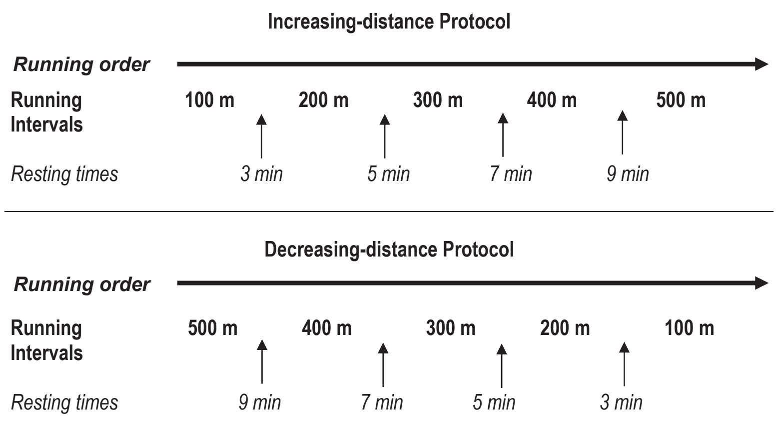


Figure 1. The training protocol for the increasing-distance and decreasing-distance groups

a 400 m lap rubber (Recortan) made track. Worm up before each training session included about 8 min of jogging, 10 min of stretching exercises and 3–4 40–60 m sub-maximal runs at 70–80% of maximal sprint speed. Training sessions were performed during the late afternoon, 3–4 hours after lunch, with an air temperature of 24–26°C. Participants were instructed to drink 500 ml of water 30 min before each training session. None of the participants was taking any food supplements.

Testing Procedures

In order to evaluate field performance capabilities changes, participants performed two field tests on non-consecutive days, during the two weeks prior to the beginning and the two weeks after completing the six weeks training programs. Both tests were performed at the same time of the day, under the same environmental conditions, and with the same technician who was blinded to the training-group affiliation. Due to the great sensitivity of environmental conditions on scores during the field test, the technicians stuff made shore that weather conditions were similar for the pre and the post treatment testing sessions. The performance evaluation, in each set of tests, included an aerobic- and an anaerobic-type field tests.

Aerobic Test – 2,000 m Run: The 2,000 m running test was used to evaluate the participants' aerobic performance capability. In order to complete the run the participants were required to complete five laps on a 400 m track. Running times were taken by hand using a standard stopwatch, and were rounded off to the nearest 0.1 sec. The run was performed in homogenous sub-groups of 8–10 participants each according to their personal records. Although each participant ran as fast as he could, each had the liberty to use his own running tactics to produce the best possible result.

Anaerobic Test – 300 m Run: The 300 m running test was used to evaluate the participants' anaerobic endurance capability. The run was performed on a 400 m lap track. Running times were taken by hand using a standard stopwatch, and were rounded off to the nearest 0.1 sec. The participants ran the 300 m in small homogenous sub-groups of 5–6 participants with similar capabilities. Each participant used his own running tactics to produce the best possible result.

Environmental conditions in the two field tests were comfortable and similar (morning: 8:30am, temperature: 24–26ºC, wind: 0.1–0.3 m/sec, humidity: 40–50%) for all groups. All the participants were familiar with the two runs – the 2,000 and the 300 m – as they ran them before during fitness and track and field practical classes. Before each tests, participants performed a standard warm-up including 8 min of jogging, followed by a 10 min stretching exercise and two 30 m sub-maximal runs (at approximately 90% of maximal sprint speed). In order to eliminate unnecessary fatigue, participants were instructed to avoid any intense physical activity 48 hr before each test.

Statistical analyses

A two-way repeated measure analysis of variance was used to compare performance capabilities, with time serving as the within-group and training protocol as the between-group factor. In addition, we used an unpaired t-test to compare the percent change differences in 2,000 m and 300 m running time scores between the two training protocols. A Cohen's d-effect size (ES) was also performed to demonstrate the magnitude of training effect in each group. Data are presented as mean ± s. Significant level was set at $p \leq 0.05$.

Results

There were no baseline differences in body mass (72 ±2.4 and 74.2 ±3.3 kg), height (1.74 ±0.1 and 1.75 ±0.1 cm), body fat percentage (12.6 ±3.1 and 12.9 ±2.9), or lean body mass (59.6 ±4.3 and 61.3 ±6.7 kg) between the groups prior to the training programs.

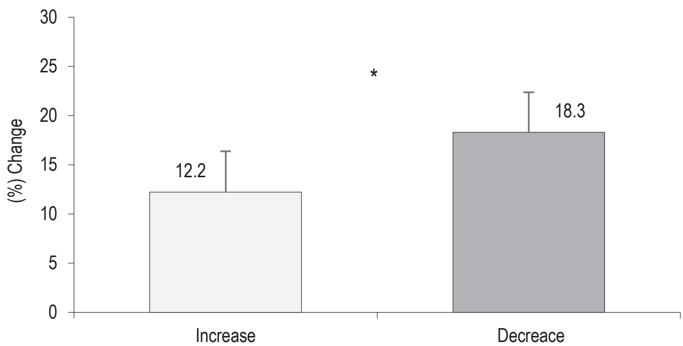
Changes in aerobic capability (as measured by the 2,000 m running times) are presented in Table 1. There were no baseline differences in 2,000 m running times between the groups prior to the training. Both training programs led to a significant improvement in 2,000 m running times [F (1, 38) = 383.30; P < 0.000; ES = 0.91], with a significant group interaction [F (1, 38) = 14.41; P < 0.001; ES = 0.52]. In addition, the percent change in 2,000 m running time was significantly greater in the DTG compared to the ITG program (Figure 2).

Table 1. The effect of the different training programs on aerobic and anaerobic performance capabilities (Means ± s)

	Increasing-distance group (n = 20)			Decreasing-distance group (n = 20)		
Variables	Pre	Post	ES	Pre	Post	ES
2,000 (min/sec)	9:33 ±1:02	8:55 ±0:50*	0.02	9:27 ±1.01	7:58 ±0:48**	0.68
300 (sec)	52.8 ±3.6	44.6 ±3.8*	0.25	53.6 ±2.7	42.2 ±2.8 **	0.73

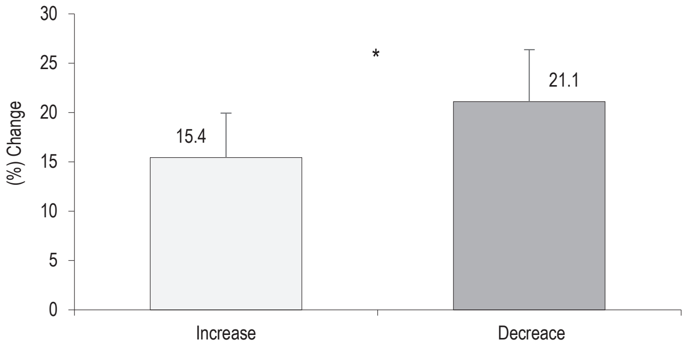
*p < 0.05; **p < 0.01 for within group changes; ES: effect size.

Changes in anaerobic capability (as measured by the 300 m running times) are presented in Table 1. There were no baseline differences between the groups in the 300 m running times prior to training. Both training programs led to a significant improvement in 300 m running times [F (1, 38) = 479.90; P < 0.000; ES = 0.93], with a significant group interaction [F (1, 38) = 12.92; P < 0.001; ES = 1.02]. In addition, the percent change in the 300 m running time was significantly greater in the DTG compared to the ITG program (Figure 3).



*p < 0.05 for between group change.

Figure 2. The effect of the two training programs on percent changes of 2,000 m run time



*p < 0.05 for between group change.

Figure 3. The effect of the two training programs on percent changes of 300 m run time

Discussion

The findings of the present study indicate that both training programs significantly improved aerobic and anaerobic performance capabilities measured by the 2,000 m and 300 m running times. More importantly, it was found that the improvement in both the aerobic and anaerobic capabilities was significantly greater in the DTG compared to the ITG.

These findings are agreement with previous relevant studies. Systematic reviews and reports have indicated that interval-training in recreationally active individuals significantly improves aerobic fitness and endurance performance (Garcia-Hermoso et al., 2016; Gist, Fedewa, Dishman, Cureton, 2014; Lindsay et al., 1996; Sloth, Sloth, Overgaard, Dalgas, 2013). An improved capacity of aerobic metabolism, as evidenced by an increased expression of type I fibers, capillarization, and oxidative enzyme activity (Gibala et al., 2006; Harmer et al., 2000; Helgerud et al., 2007), is the most common response to interval-training in active individuals. The improvement in interval-training was found to be significantly greater than the improvement following continuous sub-maximal training (Burgomaster et al., 2008; Milanovic, Sporiš, Weston, 2015; Stepto, Hawley, Dennis, Hopkins, 1999; Weston, Taylor, Batterham, Hopkins, 2014). In addition, when compared to continuous sub-maximal endurance training, interval-training presents an effective alternative, with a much lower volume of activity and potentially reduced time commitment (Foster et al., 2014). Low-volume high-intensity interval-training may also have the potential to improve anaerobic performance, as it enhances anaerobic metabolism (Laursen, Blanchard, Jenkins, 2002; Meckel et al., 2011; Spriet, 1995). In meta-analyses of Sloth et al. (2013) and Gist et al. (2014), low-volume high-intensity interval training was shown to consistently improve anaerobic peak and mean power. This improvement was expected, given that these trainings were found to induce glycolytic enzymes activity, muscle buffering capability, and ionic regulation related to anaerobic metabolism (Billat, 2001; Weston et al., 1996).

The main finding of the present study demonstrated that the improvement in the aerobic (2,000 m run time) and anaerobic (300 m run time) performance capabilities was significantly greater in the DTG compared to the ITG (Figure 2 and 3). This is in agreement with a recent study by Sindiani et al. (2017) who demonstrated that DTG showed significant superiority over ITG in improving aerobic (VO_2 max) and anaerobic indices (PP, MP, FI in the Wingate anaerobic test). These findings are also in line with the acute higher cardiovascular (heart rate), metabolic (lactate) and hormonal (GH) stimulus that were found in a single decreasing-distance compared to a single increasing-distance training protocol in trained athletes (Meckel et al., 1997; Meckel et al., 2011). The results of these studies may reflect the physiological load resulting from the differences in the length of intervals as well as from the duration of rest periods between intervals at the different stages of each training protocol. It is therefore suggested that the decreasing interval protocol creates a stronger physiological impact, and apparently presents a more efficient training tool than the increasing interval protocol. The superior efficiency of the decreasing training protocol is even strengthened, because significant greater improvement of the DTG compared to the ITG was seen in both the aerobic and anaerobic performances simultaneously (Figures 2 and 3). On the other hand, since the decreasing-distance training protocol is more physiologically and hormonally demanding, athletes and coaches should keep in mind that this type of interval training probably deserves longer and more efficient recovery modalities.

Conclusions

The present study demonstrated that six weeks of both an increasing-distance and a decreasing-distance interval-training program significantly improved aerobic and anaerobic performance capabilities. More importantly, the study's findings revealed that the decreasing-distance interval-training program induced greater improvement than the increasing-distance interval-training program in both aerobic and anaerobic fitness of young active participants.

Given the varying impacts of the two interval-training protocols in our study, coaches and athletes should be aware of the different recovery times or modes of training sessions required following each of these protocols. These may be considered when designing a micro- or a macro-cycle training period of aerobic- or anaerobic-type young athletes.

References

Billat, L.V. (2001). Interval training for performance: A scientific and empirical practice. *Sports Medicine*, *1* (31), 13–31.

Burgomaster, K.A., Howarth, K.R., Phillips, S.M., Rakobowchuk, M., MacDonald, M.J., McGee, S.L., Gibala, M.J. (2008). Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. *The Journal of Physiology*, *1* (586), 151–160.

Foster, C., Farland, C.V., Guidotti, F., Harbin, M., Roberts, B., Schuette, J., …, Porcari, J.P. (2015). The effects of high intensity interval training vs steady state training on aerobic and anaerobic capacity. *Journal of Sports Science and Medicine*, *4* (14), 747–755.

Garcia-Hermoso, A., Cerrillo-Urbina, A.J., Herrera-Valenzuela, T., Cristi-Montero, C., Saavedra, J.M., Martinez-Vizcaino, V. (2016). Is high-intensity interval training more effective on improving cardiometabolic risk and aerobic capacity than other forms of exercise in overweight and obese youth? A meta-analysis. *Obesity Reviews*, *6* (17), 531–540.

Gibala, M.J., Little, J.P., Van Essen, M., Wilkin, G.P., Burgomaster, K.A., Safdar, A., …, Tarnopolsky, M.A. (2006). Short-term sprint interval versus traditional endurance training: Similar initial adaptations in human skeletal muscle and exercise performance. *The Journal of Physiology*, *3* (575), 901–911.

Gillen, J.B., Gibala, M.J. (2014). Is high-intensity interval training a time-efficient exercise strategy to improve health and fitness? *Applied Physiology, Nutrition, and Metabolism*, *3* (39), 409–412.

Gist, N.H., Fedewa, M.V., Dishman, R.K., Cureton, K.J. (2014). Sprint interval training effects on aerobic capacity: A systematic review and meta-analysis. *Sports Medicine*, *2* (44), 269–279.

Harmer, A.R., McKenna, M.J., Sutton, J.R., Snow, R.J., Ruell, P.A., Booth, J., Carey, M.F. (2000). Skeletal muscle metabolic and ionic adaptations during intense exercise following sprint training in humans. *Journal of Applied Physiology*, *5* (89), 1793–1803.

Hazell, T.J., MacPherson, R.E., Gravelle, B.M., Lemon, P.W. (2010). 10 or 30-s sprint interval training bouts enhance both aerobic and anaerobic performance. *European Journal of Applied Physiology*, *1* (110), 153–160.

Helgerud, J., Hoydal, K., Wang, E., Karlsen, T., Berg, P., Bjerkaas, M., Hoff, J. (2007). Aerobic high-intensity intervals improve VO_2 max more than moderate training. *Medicine & Science in Sports & Exercise*, *4* (39), 665–671.

Laursen, P.B., Blanchard, M.A., Jenkins, D.G. (2002). Acute high-intensity interval training improves Tvent and peak power output in highly trained males. *Canadian Journal of Applied Physiology*, *4* (27), 336–348.

Laursen, P.B., Jenkins, D.G. (2002). The scientific basis for high-intensity interval training. *Sports Medicine*, *1* (32), 53–73.

Lindsay, F.H., Hawley, J.A., Myburgh, K.H., Schomer, H.H., Noakes, T.D., Dennis, S.C. (1996). Improved athletic performance in highly trained cyclists after interval training. *Medicine & Science in Sports & Exercise*, *11* (28), 1427–1434.

MacDougall, J.D., Hicks, A.L., MacDonald, J.R., McKelvie, R.S., Green, H.J., Smith, K.M. (1998). Muscle performance and enzymatic adaptations to sprint interval training. *Journal of Applied Physiology*, *6* (84), 2138–2142.

Meckel, Y., Gefen, Y., Nemet, D., Eliakim, A. (2012). Influence of short vs. long repetition sprint training on selected fitness components in young soccer players. *The Journal of Strength & Conditioning Research*, *7* (26), 1845–1851.

Meckel, Y., Nemet, D., Bar-Sela, S., Radom-Aizik, S., Cooper, D.M., Sagiv, M., Eliakim, A. (2011). Hormonal and inflammatory responses to different types of sprint interval training. *The Journal of Strength & Conditioning Research*, *8* (25), 2161–2169.

Meckel, Y., Grodjinovsky, A., Ben-Sira, D., Rotstein, A., Sagiv, M. (1997). Cardiovascular and metabolic responses to two different sprint training. *International Journal of Sports Cardiology*, *6*, 9–14.

Milanović, Z., Sporiš, G., Weston, M. (2015). Effectiveness of high-intensity interval training (HIT) and continuous endurance training for VO_2max improvements: A systematic review and meta-analysis of controlled trials. *Sports Medicine*, *10* (45), 1469–1481.

Rakobowchuk, M., Tanguay, S., Burgomaster, K.A., Howarth, K.R., Gibala, M.J., MacDonald, M.J. (2008). Sprint interval and traditional endurance training induce similar improvements in peripheral arterial stiffness and flow-mediated dilation in healthy humans. *American Journal of Physiology-Regulatory, Integrative and Comparative Physiology*, 1 (295), R236–R242.

Rodas, G., Ventura, J.L., Cadefau, J.A., Cussó, R., Parra, J. (2000). A short training programme for the rapid improvement of both aerobic and anaerobic metabolism. *European Journal of Applied Physiology*, *5–6* (82), 480–486.

Sindiani, M., Eliakim, A., Segev, D., Meckel, Y. (2017). The effect of two different interval-training programmes on physiological and performance indices. *European Journal of Sport Science*, 1–8.

Sloth, M., Sloth, D., Overgaard, K., Dalgas, U. (2013). Effects of sprint interval training on VO_2max and aerobic exercise performance: A systematic review and meta-analysis. *Scandinavian Journal of Medicine & Science in Sports*, *6* (23), e341–e352.

Spriet, L.L. (1995). Anaerobic metabolism during high-intensity exercise. In: M. Hargreaves (ed.), *Exercise metabolism* (pp. 1–40). Champaign, IL: Human Kinetics.

Stepto, N.K., Hawley, J.A., Dennis, S.C., Hopkins, W.G. (1999). Effects of different interval-training programs on cycling time-trial performance. *Medicine & Science in Sports & Exercise*, *31*, 736–741.

Weston, M., Taylor, K.L., Batterham, A.M., Hopkins, W.G. (2014). Effects of low-volume high-intensity interval training (HIT) on fitness in adults: A meta-analysis of controlled and non-controlled trials. *Sports Medicine*, *7* (44), 1005–1017.

Weston, A.R., Myburgh, K.H., Lindsay, F.H., Dennis, S.C., Noakes, T.D., Hawley, J.A. (1996). Skeletal muscle buffering capacity and endurance performance after high-intensity interval training by well-trained cyclists. *European Journal of Applied Physiology and Occupational Physiology*, *1* (75), 7–13.

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