ORIGINAL RESEARCH ARTICLE

Efficacy of a modified tapering protocol on swimming performance

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Abstract

Objective. The aim of this study was to determine any difference in performance following two different tapering protocols after a period of heavy training.

Design. Twelve swimmers who regularly trained at a high volume and intensity were recruited and trained together for 3 weeks. They were then randomly split into two groups (*N*=6 per group). One group underwent a standard taper protocol, while the second followed a modified taper in which training load was gradually resumed for 1 week following a standard taper. Performance assessment following tapering consisted of 2 swims over a distance of 200 m, with a recovery period of 5 hours between swims. After resuming normal training, subjects tapered a second time, each group following the alternate protocol.

Outcome measures. Total time and split times for each length, stroke rate, distance per stroke, and stroke index in a performance swim were determined as well as heart rate (HR), profile of mood state (POMS), rating of perceived exertion (RPE) and muscle pain during each taper.

Results. Mean swim times for the modified and conventional tapers were 134.7±9.1 and 134.7±9.3 seconds, respectively (mean ±SD). There was also no difference in the split times between groups, although both became slower in the final three laps. Stroke rate, distance per stroke, and stroke index were also not different between protocols. There were no differences between protocols in HR, RPE or rating of muscle pain over the duration of the tapering period. However, there was a significant reduction in HR on day 5 of both tapers and a lower POMS on days 3, 4 and 5 on the standard taper protocol. At the time of the performance swim, however, there was no difference in POMS.

Conclusion. There were no performance or physiological advantages from the modified tapering protocol.

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Introduction

Performance can be improved in hard-training athletes by reducing the amount of training before competition, a procedure commonly known as tapering.[11] Various studies on swimmers have determined that tapering can improve performance by 3%.[8,11] Similar improvement (3%) has also been shown in runners subsequent to a tapering regimen.[6,9]

Many training variables can be altered during a tapering regimen. This includes frequency of training, duration, intensity and volume of training. Scientific studies have shown that an optimal taper involves a reduction in training volume, but with intensity maintained as high as during hard training.[11,14] Similarly, the frequency of training sessions during a taper protocol is kept the same as during normal training. The recommended duration of a tapering protocol ranges from 7 to 14 days. This constitutes a standard taper protocol as used by most swimmers and runners world-wide.[6,8]

One concern of athletes commencing a tapering regimen is the possible negative effect of detraining as a result of the reduced training load during the taper. However, it has been established that detraining does not occur during the period of a properly constructed taper; rather, performance in competition is maximised.[7,12]

In a study on swimmers, it was shown that neural and cognitive capacities increase in efficiency as a result of a tapering protocol, and strength and muscle power increase markedly. As a result, propelling efficiency of swimming strokes is increased.[13] Optimal performance will occur when physiological capacity is maximised as the negative influences of fatigue due to a heavy training load are reduced, but before detraining occurs.[10,16] To achieve this, the optimal duration of the taper should be approximately 2 - 4 weeks,[5] and can be either a progressive reduction in training load or a step reduction. However, a progressive reduction may be more effective than a step reduction.[1]

Anecdotal evidence has suggested that it may be possible to improve on the standard taper protocol, since it has been observed that some athletes do not always perform as well as expected immediately after such a taper as theory and studies suggest, but in fact run or swim faster times a week subsequent to the taper, when normal training has been resumed. Thus it appears that there may be a delay before the full benefit of the taper is realised.

A modified taper in which a standard taper is followed by a return to previous training load before competition may therefore be a superior tapering technique. This study aims to determine whether such a modified tapering protocol produces a better performance than a standard taper protocol in highly trained swimmers.

Methods

Subjects

Sixteen swimmers who were members of a local swimming club were selected to participate in the study. All were top provincial or national swimmers who were in current competitive hard training before the commencement of the study.

TABLE I. Overview of tapering protocols

		Mon	Tue	Wed	Thu	Fri	Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Mod	Dist (m)	2200	2400	2100	2400	2300	0	0	3600	4200	4600	5300	2900	Gala
		T	T	T	T	T	T	T	R	R	R	R	Rec	
Std	Dist (m)	4100	4200	4000	4100	4200	0	0	2200	2400	2100	2400	2300	Gala
		H	H	H	H	H	T	T	T	T	T	T	T	

Mod = modified taper; Std = standard taper; T = taper at 50% volume; R = return to hard training load; Rec = recovery session; H = normal hard training volume.

All subjects were informed of the nature of the study and a consent form was signed before the commencement of the study, which was granted approval by the Research Ethics Committee of the University of Cape Town.

All swimmers were between 13 and 22 years of age and had been competing for at least 5 years. One subject was excluded from the study due to irregular attendance during the training protocol. Three more were excluded due to injuries. Therefore, 12 swimmers completed the study and these data are reported.

Total control of the training programme was granted to the researcher by the coach for the duration of the study.

To improve compliance and motivation of the subjects, an incentive was used. This consisted of a prize given to the swimmer who attended the most sessions throughout the study and who recorded the fastest average time for all the performance swims.

Training protocol

A two-group crossover experimental design was followed. The training protocol had four components consisting of hard training (continued from the normal hard training of the swimmers), taper, performance swim (gala) and return towards normal (hard) training.

Hard training

All subjects in the study underwent a 3-week hard training lead-in phase in which the swimmers became accustomed to the attention given to them as a result of participating in the study, and meeting as a group for testing. The training programme followed was similar to the standard (hard) training programme used by each swimmer. Group training was conducted at the same time in the evening, excluding Saturdays and Sundays. The pool temperature was 26.8° (± 0.9°).

The supervised hard training protocol comprised 15 pool sessions. Total distance swum (overall distance for 15 sessions) was 67 800 m with an average of 4 520 m (± 390 m) per training session in the pool. Land training consisted of general body-strengthening exercises for the upper, middle and lower body. The land training took place on the pool deck.

Taper

No land training took place during the taper phase. For this phase, the swimmers were randomly assigned into two groups. Details of the protocols are shown in Table I. The first group (*N*=6) underwent the modified tapering protocol which consisted of 7 days of training at 50% of normal training load, but with intensity maintained as high as that during the hard training phase. After the 7-day period, the swimmers returned progressively towards hard training for 4 sessions (Monday - Thursday). Specifically, there was a gradual increase in training volume during these 4 sessions, until the volume of the previous hard cycle was reached. The fifth day was a recovery session of reduced volume, before performance testing the following day.

The second group (*N*=6) underwent the same standard taper protocol (50% of normal volume), but without the 4 days of return to normal training volume.

The total distance swum during both tapers was identical. Specifically, a total distance of 11 400 m was swum at an average of 2 280 m (± 116 m) per session.

Measurements during tapering

Heart rate testing

Heart rate (HR) was measured during both taper protocols. The HR measurement was done before training, on alternate days. Swimming 'pullers' were used for these tests, which consisted of modified hand paddles as used in swimming training, connected to rubber bands. Some of the swimmers in the study had used the pullers previously as a training tool. Those swimmers who had not, familiarised themselves with the apparatus before testing commenced.

The pullers were mounted above the swimmer so that the paddle rested at full arm extension above the swimmer's head when standing. Any discrepancy caused by the swimmer's individual height was corrected by placing mats under the swimmer's feet.

The swimmers pulled from the extended position above the head, downward to the hips. The elbows remained in a partially flexed position and did not bend while performing the movement. The paddles were hinged to allow for rotation through the pulling movement. Each puller had a set resistance determined by the length of the rubber band, with the load exerted measured using a hand scale, and varied from 12 to 14.5 kg.

A Polar Heart Rate Monitor (Vantage XL, USA) was used to measure HR and a Seiko metronome (LED and Audio signal) was used to set the cadence for each swimmer. The metronome settings varied from 56 to 84 beats per minute. Each swimmer kept their individual cadence at the specified rate, determined according to the specific strength of the swimmer and each used the same puller, cadence and mat setting for the entire study. The swimmers were instructed to pull for 3 minutes at their prescribed cadence while wearing the heart rate belt and transmitter. At the end of the 3 minutes, a 1-minute recovery was recorded during which the swimmers remained standing next to the pullers. HR data were recorded in 5-second intervals and downloaded onto a computer after each session. This included peak HR during the 3-minute workout, the 1-minute recovery HR, and the rate of decline, calculated as the peak HR minus the 1-minute recovery HR. It must be noted that this series of tests are not specific to swim performance and any performance improvement in such tests may not translate to improved swimming performance.

Mood states

A Profile of Mood State (POMS) questionnaire was used to assess mood state.[16] The POMS questionnaire assesses total mood disturbance and 6 different mood states (tension, depression, anger, vigour, fatigue and confusion). The swimmers were asked to com-

TABLE II. Summary of the distances swum during the training protocols		
	Total distance swum	**Average per training day**
Hard training (while in study)	67 800 m	4 520 m
Final 7-day taper period	11 400 m	2 280 m (50% of hard training)
Overall 2-week taper*	34 000 m	3 400 m

*This included the taper training and the return to hard training and the continued hard training components, depending on taper protocol followed.

plete the questionnaire every evening after each training session during the taper protocol.

Only 10 of the swimmers completed all the POMS questionnaires correctly and these data are reported. The raw scores were converted to a standard score by subtracting the scale values of ‘tension’, ‘depression’, ‘anger’, ‘fatigue’ and ‘confusion’ from the scale value of ‘vigour’ and adding a constant of 100. An overall higher score indicates an improved mood state.

Muscular pain and rating of perceived exertion (RPE)

A Rating of Pain score was obtained from each swimmer during the taper protocol in which the swimmers rated their degree of muscular pain against a numerical scale. The scale ranged from 0 (no pain at all) to 10 (maximal pain). This was done every evening prior to HR testing and training session. An RPE (Borg Scale) was also obtained from each swimmer. These data were collected daily.

Performance swim (gala)

A gala to assess performance took place immediately after the taper and was split into two sessions. The first took place from 12h30 until 13h30. The second session took place from 17h00 until 18h00. This allowed the swimmers a full recovery between sessions, in which they were asked to perform one maximal 200 m swim of their best stroke.

Measures of performance

The following data were recorded during the performance assessment: total time (seconds) for the swim (two Seiko stop watches were used and the average of the two times was entered as the time for the swim), time (seconds) for each 25 m length of the pool (lap split), three timed strokes (as the swimmer crossed the midline of the pool, three strokes were timed using a Seiko interval timer stopwatch and recorded as strokes/min), and the number of strokes taken per 25 m length (a volunteer counted the number of strokes taken). From these data the following was calculated: distance per stroke (meters/stroke; calculated by dividing the distance swum (25 m) by the number of strokes taken), swim velocity (meters/sec; calculated by dividing the total distance swum by the time) and stroke index (swimming velocity x distance per stroke). The stroke index is useful in evaluating a swimmer’s technique and efficiency. The higher the index, the more efficient the swimmer. At a given velocity, the swimmer that moves the greatest distance per stroke has the most effective technique.[2]

The performance measures for the two swims were then added together and an average score calculated.

Return to normal training

Following the performance test (gala) the swimmers returned to the hard training cycle during which the same training was followed as before. After a month on the hard training cycle, the groups started the alternate taper protocol to that followed previously, followed by another gala for performance assessment (the same hard training, land training, testing times and environment, testing methods and assistants were used during the entire study).

A summary of the distances swum during the different phases of the study is shown in Table II.

TABLE III. Anthropometrical data of the subjects

	Subject	Height (cm)	Age (years)	Weight (kg)	Body fat (%)
Group A	1	192.3	22	88.2	21.2
	2	181.2	17	71.4	18.1
	3	172.5	17	68.3	18.5
	4	172.5	16	65.5	17.5
	5	161.4	13	51.4	22.2
	6	15 9.3	14	49.3	21.3
	Mean	172.3	16	65.7	19.8
	SD	11.2	2	13.0	1.8
Group B	1	178.3	16	72.3	16.5
	2	174.4	16	68.4	25.7
	3	199.2	16	82.3	14.9
	4	148.7	13	47.6	28.1
	5	166.6	15	54.7	13.2
	6	188.4	16	68.5	14.5
	Mean	175.9	15	65.6	18.8
	SD	15.9	1	11.4	5.8

Statistics

All data were expressed as mean ± SD. An analysis of variance with repeated measures was used to assess difference between protocols (stroke rate, distance per stroke, swim velocity, stroke index, 1-minute recovery heart rate, peak heart rate, and rate of decline). Where significant differences were found, a Scheffe's *post-hoc* test was used.

A paired *t*-test for dependant samples was used to analyse the data obtained for performance time at the end of each taper. The Friedman analysis of variance test for non-parametric data was used to analyse the subjective ratings of each taper (muscle pain, POMS and RPE). The Mann-Whitney test was used to determine whether differences occurred between specific time points. Statistical significance was accepted when $p<0.05$.

Results

Anthropometry

Basic anthropometrical data for all the subjects are presented in Table III. Measurements of weight and height were taken at the commencement of the training protocol using a SECA model 708 scale. Body fat measurements were taken using the four-site method described by Durnin and Womersley.[4]

Heart rate

Peak heart rate

There was no significant difference ($p>0.05$) in the peak HR between the two tapers. However, peak HR on day 9 of each taper was significantly lower than on days 1 and 3.

1-minute recovery heart rate and rate of decline

There were no significant differences between protocols in either the 1-minute recovery HR or the rate of decline.

Profile of mood state

The POMS score was found to be significantly ($p<0.05$) reduced on the standard protocol on days 3, 4, and 5 of the taper (Fig. 1).

Rating of perceived exertion

Significant differences were found in RPE between the modified and standard protocols on days 3, 5 and 9 of the tapers (Fig. 2). However, there was no significant difference at the end of the tapers when the performance swim was undertaken. There was a significant change over the duration of the tapers.

Muscular pain rating

There were no significant differences between taper protocols or over the duration of the taper protocol.

Distance per stroke and stroke index

There were no significant differences between the protocols in either distance per stroke or stroke index, but both were significantly less on the final three laps of the performance swims than at the start ($p<0.05$) (Fig. 3).

Stroke rate

There were no significant differences either between protocols or on the different laps of the performance swim.

Swim velocity

There were no significant differences in the swim velocity on each lap between the taper protocols. However, there was a decline in swimming velocity regardless of the taper employed (Fig. 4).

Race time

As would be expected from Fig. 4, race times were not significantly different between protocols. Swim times for individual subjects are shown in Table III.

Discussion

The objective of this study was to examine swimming performance after following a standard and a modified standard tapering protocol.

The most important finding was that there were no differences in the swim times recorded following the standard and modified tapering protocols. Of the 12 subjects, 8 recorded faster times after the standard taper (subjects 1, 2, 4, 5, 6, 7, 9, 10). After the completion of the study, each swimmer was asked which taper they favoured. Ten of the 12 swimmers favoured the standard taper (hard training followed by a standard taper before the performance swim), while only two swimmers favoured the modified taper (standard taper followed by a return to hard training before a performance swim). Interestingly, both these were distance swimmers and both recorded faster times on the modified taper. However, the two other swimmers who recorded faster times on the modified taper favoured the standard taper, despite their poorer performance after that taper protocol.

Since there were no significant differences in HR between the two taper protocols, it appears that there were no differences in the degree to which physiological stress was reduced on either protocol. However, since peak HRs were significantly reduced on day 9 of both the tapers, there appears to have been a general improvement in physiological stress response. Curiously, this was not continued through to day 11. There appears to be no logical explanation for this, other than anxiety due to the forthcoming gala the following day.

Although HR response was similar regardless of the taper protocol, RPE was lower on the standard protocol on days 3 and 5, higher on day 9, and the same on both protocols at the time of the performance swim (Fig. 2). Thus there was no apparent relationship between RPE changes and HR response, as RPE was lower on the modified taper (days 3 and 5), without a corresponding difference in HR. In the case of POMS, the scores were higher on the modified taper at the time RPE was lowest (days 3 and 5). It is difficult to ascribe any physiological significance to these responses.

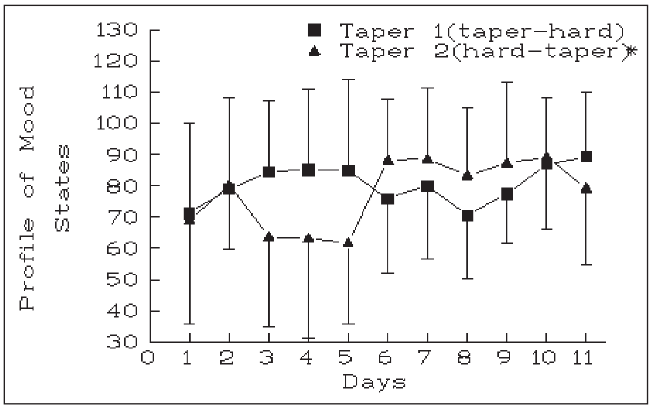

***Fig. 1.** Profile of mood states for the final 11 days of the different taper protocols (N=12). Values are expressed as mean ± SD. *p<0.03. Taper-hard = modified taper protocol; hard-taper = standard taper protocol.*

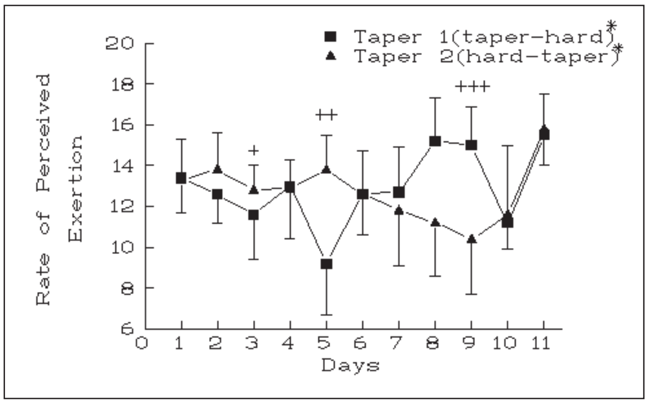

Fig. 2. RPE values for the final 11 days for the different taper protocols. *p<0.000001 over the duration of the tapering period. $^{+}$p<0.01: taper 1 (taper-hard) different to taper 2 (hard-taper) on day 3. $^{++}$p<0.0004: taper 1 (taper-hard) different to taper 2 (hard-taper) on day 5. $^{+++}$p<0.0005: taper 1 (taper-hard) different to taper 2 (hard-taper) on day 9. Values are expressed as mean ± SD. Taper-hard = modified taper protocol; hard-taper = standard taper protocol.

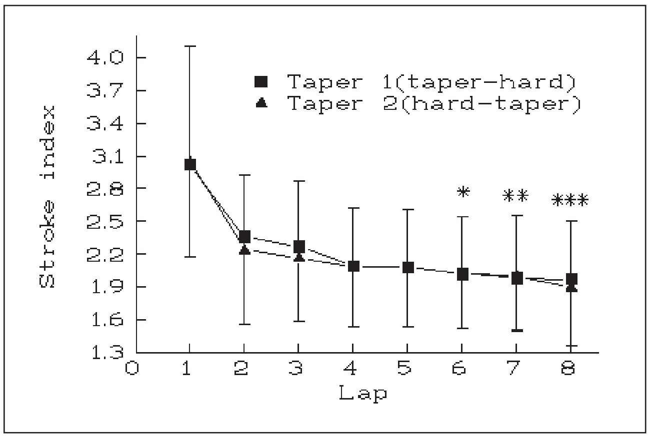

Fig. 3. Stroke index for the different tapers (N=12). Values are expressed as mean ± SD. *p<0.005: lap 6 different to lap 2. **p<0.04: lap 7 different to lap 3. ***p<0.00004: lap 8 different to lap 2. Lap 1 was not compared for significance as it included the dive. There were no differences between protocols. Taper-hard = modified taper protocol; hard-taper = standard taper protocol.

Although the tapering protocols did not result in any difference in swim performance, there were changes as the swim progressed in parameters related to performance, regardless of tapering protocol employed. Specifically, as with previous studies,[15] performance measures declined as the race progressed, i.e. distance per stroke, stroke index, and swim velocity. It has been suggested that the reduced distance per stroke later in the swim is the result of increased drag as the swimmer becomes tired.[3] The change in stroke index also indicates increased fatigue. Although these changes all indicate fatigue later in the swim, neither protocol was superior in reducing these negative effects. Nevertheless, swim velocity was significantly slower in the latter stages of the swim as a result.

In conclusion, there were no significant differences in performance due to the different taper protocols employed. The traditional taper, however, was favoured by the swimmers compared with the modified protocol. There is therefore no reason to suggest a change in tapering procedure and the anecdotal observations on which the study was

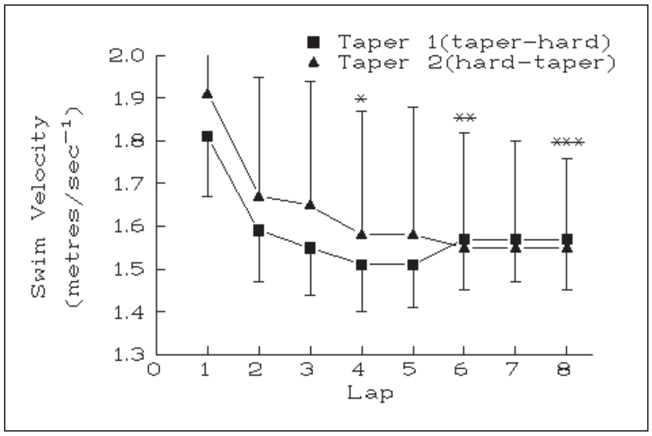

Fig. 4. The swim velocity (m.s^{-1}) for the two taper protocols (N=12). Values are expressed as mean ± SD. *p<0.0001: lap 4 different to lap 2. ** p<0.003: lap 6 different to lap 3. ***p<0.0000001: lap 8 different to lap 2. Lap 1 was not compared for significance as it included the dive. Taper-hard = modified taper protocol; hard-taper = standard taper protocol.

based, i.e. that performance may be optimal some days after a tapering protocol has been completed and normal training resumed, were not borne out by scientific investigation in this particular cohort of swimmers. However, future studies should repeat the study in which swimmers who participate in shorter or longer distance events are studied, in swimmers who use higher training volumes, and swimmers who are more uniform in age. Another type of taper for use when two competitions are in close proximity to each other should also be investigated. Finally, testing of the modified protocol in runners, in which there is a large eccentric component, should be considered.

References

1. Banister EW, Carter JB, Zarkadas PC. Training theory and taper: validation in triathlon athletes. *Eur J Appl Physiol Occup Physiol* 1999; 79: 182-91.
2. Costill DL, Kovaleski J, Porter D, Kirwan J, Fielding R, King D. Energy expenditure during front crawl swimming: predicting success in middle-distance events. *Int J Sports Med* 1985; 6: 266-70.
3. Craig AB, Jr., Skehan PL, Pawelczyk JA, Boomer WL. Velocity, stroke rate, and distance per stroke during elite swimming competition. *Med Sci Sports Exerc* 1985; 17: 625-34.
4. Durnin JV, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. *Br J Nutr* 1974; 32: 77-97.
5. Fitz-Clarke JR, Morton RH, Banister EW. Optimizing athletic performance by influence curves. *J Appl Physiol* 1991; 71: 1151-8.
6. Houmard JA. Impact of reduced training on performance in endurance athletes. *Sports Med* 1991; 12: 380-93.
7. Houmard JA, Costill DL, Mitchell JB, Park SH, Hickner RC, Roemmich JN. Reduced training maintains performance in distance runners. *Int J Sports Med* 1990; 11: 46-52.
8. Houmard JA, Johns RA. Effects of taper on swim performance. Practical implications. *Sports Med* 1994; 17: 224-32.
9. Houmard JA, Scott BK, Justice CL, Chenier TC. The effects of taper on performance in distance runners. *Med Sci Sports Exerc* 1994; 26: 624-31.
10. Mujika I. The influence of training characteristics and tapering on the adaptation in highly trained individuals: a review. *Int J Sports Med* 1998; 19: 439-46.
11. Mujika I, Padilla S, Pyne D, Busso T. Physiological changes associated with the pre-event taper in athletes. *Sports Med* 2004; 34: 891-927.
12. Neufer PD. The effect of detraining and reduced training on the physiological adaptations to aerobic exercise training. *Sports Med* 1989; 8: 302-20.

13. Rushall BS, Shewchuk ML. Effects of thought content instructions on swimming performance. *J Sports Med Phys Fitness* 1989; 29: 326-34.
14. Shepley B, MacDougall JD, Cipriano N, Sutton JR, Tarnopolsky MA, Coates G. Physiological effects of tapering in highly trained athletes. *J Appl Physiol* 1992; 72: 706-11.
15. Wakayoshi K, Yoshida T, Ikuta Y, Mutoh Y, Miyashita M. Adaptations to six months of aerobic swim training. Changes in velocity, stroke rate, stroke length and blood lactate. *Int J Sports Med* 1993; 14: 368-72.
16. Wittig AF, Houmard JA, Costill DL. Psychological effects during reduced training in distance runners. *Int J Sports Med* 1989; 10: 97-100.

ORIGINAL RESEARCH ARTICLE

Differences in muscle pain and plasma creatine kinase activity after 'up' and 'down' Comrades marathons

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Abstract

Objective. The aim of this study was to compare the acute changes in muscle pain and plasma creatine kinase (CK) activity following the 'up' and 'down' Comrades marathon.

Design. This was a quasi-experimental design. Eleven male runners (39.7±9.3 years) completed the 'up' Comrades marathon, and 11 male runners (41.0±8.4 years) completed the 'down' Comrades marathon the following year. Maximum oxygen consumption and peak treadmill running speed were measured 2 weeks before the race. Daily measurements of muscle pain and plasma creatine kinase (CK) activity were recorded 1 day before, and for 7 days after the race.

Results. Muscle pain remained significantly elevated for up to 7 days after the Comrades marathon, compared with pre-race values ($p<0.0009$). The pain scores following the 'down' run were significantly higher than the pain scores following the 'up' run for at least 7 days after the race ($p<0.004$). Plasma CK activity remained significantly elevated for up to 5 days after the Comrades marathon, compared with pre-race values ($p<0.007$). Plasma CK activity following the 'down' run was significantly higher than the plasma CK activity following the 'up' run for 5 days after the race ($p<0.04$). A high degree of intra-individual variability in plasma CK activity was observed.

Conclusions. The 'down' Comrades marathon causes significantly more muscle pain and plasma CK activity compared with the 'up' Comrades marathon. Further studies are required to accurately define the regeneration of muscle following the Comrades marathon.

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Introduction

The Comrades marathon is a 90 km ultramarathon race, run annually between Durban and Pietermaritzburg, South Africa. However, the start and finish of the race alternate each year, and the race is therefore run in different directions. In the 'up' run the race starts at sea level in Durban, and runners ascend to the finish in Pietermaritzburg, at 650 m above sea level. The highest point in the race is 870 m above sea level. In the 'down' run, the race starts in Pietermaritzburg, and runners descend to the finish in Durban.[11]

Marathon and ultramarathon races impose severe physiological stresses on runners.[6,17] Previous studies on runners of the 90 km Comrades marathon have provided information regarding changes in ECG activity,[13] serum enzyme activities, fluid balance,[12] renal function,[19] factors explaining the development of hyponatraemic encephalopathy,[18] and the decrement in muscle power associated with muscle damage.[6]

It is well documented that muscle damage is a common occurrence associated with distance running.[6,17] Exercise-induced muscle damage is characterised by a disruption of the sarcolemma,[2] sarcotubular system,[2,4] contractile components of the myofibril, the extracellular matrix and the cytoskeleton.[15] Distance running is