Physiological Effects of Tapering and Detraining in World-Class Kayakers

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ABSTRACT

GARCÍA-PALLARÉS, J., L. SÁNCHEZ-MEDINA, C. E. PÉREZ, M. IZQUIERDO-GABARREN, and M. IZQUIERDO. Physiological Effects of Tapering and Detraining in World-Class Kayakers. *Med. Sci. Sports Exerc.*, Vol. 42, No. 6, pp. 1209–1214, 2010. **Purpose**: This study analyzed changes in neuromuscular, body composition, and endurance markers during 4 wk of tapering and subsequent 5 wk of reduced training (RT) or training cessation (TC). **Methods**: Fourteen world-class kayakers were randomly assigned to either a TC (n = 7) or an RT group (n = 7). One-repetition maximum (1RM) strength, mean concentric velocity with 45% 1RM ($V_{45\%}$) in the bench press (BP) and prone bench pull (PBP) exercises, and body composition assessments were conducted at the start (T0) and end (T1) of a 43-wk training program, after tapering for the world championships (T2) and after TC or RT (T3). A graded exercise test on a kayak ergometer for determination of maximal oxygen uptake at T0, T1, and T3 was also performed. **Results**: After tapering, no significant changes were observed in 1RM or $V_{45\%}$. TC resulted in significantly greater declines in 1RM strength (−8.9% and −7.8%, $P < 0.05$, respectively, for BP and PBP) than those observed for RT (−3.9% and −3.4%). Decreases in $V_{45\%}$ in BP and PBP were larger for TC (−12.6% and −10.0%) than for RT (−9.0% and −6.7%). Increases in sum of eight skinfolds were observed after both TC and RT, whereas declines in maximal aerobic power were lower for RT (−5.6%) than for TC (−11.3%). **Conclusions**: Short-term TC results in large decreases in maximal strength and especially $V_{45\%}$ in highly trained athletes. These results suggest the need of performing a minimal maintenance program to avoid excessive declines in neuromuscular function in cases where a prolonged break from training is required. **Key Words:** TRAINING CESSATION, REDUCED TRAINING, MAXIMAL STRENGTH, MUSCLE POWER, CANOEING

A well-known and proven effective coaching strategy for improving sports performance before main competition events is to incorporate a tapering phase of significantly reduced training (RT) volume while the intensity is kept high (8,17,20,23,24). It is believed that the taper enhances performance by allowing greater recovery (8,23,24). Thus, it has been previously reported that after a period of tapering, moderately strength-trained subjects improved low-velocity isokinetic strength performance of the elbow flexors for at least 8 d (8). Izquierdo et al. (17) found that 4 wk of tapering resulted in further increases for upper and lower body maximal strength and muscle power after periodized training in strength-trained athletes. Similarly, several studies that examined the effects of tapering in endurance athletes have attributed gains in performance to increased levels of muscular force and power (12,25,27,29).

The incorporation of periods of 3–6 wk of training cessation (TC) after the conclusion of the main event of the season to allow physical and mental recovery before the start of a new training cycle is a common training practice in many sports. In these situations, training reduction is generally preferred over complete exercise stoppage because it seems to be more effective to avoid the negative impact of insufficient training stimuli on athletic performance (21). The magnitude of performance declines observed after detraining periods appears to be related to the chosen recovery strategy (i.e., reduced training (RT) or complete training cessation (TC)), initial fitness level, and total time under reduced or absence of training stimuli (20–22).

Current research seems to indicate that neuromuscular performance is more susceptible to decline because of detraining in highly trained athletes compared with recently or moderately trained individuals (17,22). Thus, in experienced, strength-trained athletes, pronounced decreases in maximal dynamic strength in typical weight-training exercises such as bench press (BP; 9%), squat (10%–12%), and leg-extension (12%) have been reported after 4–8 wk of TC (9,11,17), whereas in shorter periods of TC (2 wk), declines in muscle strength seem to be much lower (13) or

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Submitted for publication May 2009.
Accepted for publication November 2009.

0195-9131/10/4206-1209/0
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DOI: 10.1249/MSS.0b013e3181c9228c

nonexistent (14). By contrast, in recently or recreationally trained athletes, strength gains after short-term TC (4–6 wk) seem more readily retained (15,18,28). In addition, muscle power seems to be lost at a greater rate than strength after detraining (17,18,26) especially among highly trained athletes, although increased maximal rate of force development (16) and phenotypic shift toward faster muscle characteristics (2,29) consequent to detraining have also been documented. To date, the majority of research that has studied the neuromuscular changes induced by tapering and detraining has used previously untrained or moderately trained participants. However, little is known about the consequences that a taper and a short-term detraining period after a concurrent endurance and periodized heavy and explosive resistance training program could have on neuromuscular performance markers in highly trained strength and endurance athletes (e.g., Olympic kayakers).

Therefore, the aim of this study was to examine changes in selected parameters of muscle strength and velocity at maximum power loads, body composition, and endurance performance brought about by a period of 5 wk of either RT or complete TC after an initial training program of a 43- and a 4-wk tapering phase in a group of world-class kayakers.

METHODS

Subjects. Fourteen male, elite flat-water kayak paddlers (including 10 finalists at world championships and 2 Olympic gold medalists) volunteered to take part in this study. Characteristics of participants (mean ± SD) were as follows: age = 25.2 ± 2.5 yr, body mass = 84.0 ± 5.5 kg, height = 1.81 ± 0.04 m; training experience = 11.1 ± 2.7 yr, and annual paddling volume = 4415 ± 374 km. Paddlers had at least 2 yr of familiarization with the testing procedures used in this investigation, and all were part of the same squad (i.e., Spanish canoeing national team). The study was approved by the Bioethics Commission of the University of Seville, and written informed consent was obtained from athletes before participation.

Study design. After a full season (43 wk) of combined strength and endurance training, subjects completed a 4-wk tapering (TAP) phase to maximize performance in the Flat-water Racing World Championship, which had been established as their main objective of the season. A 5-wk detraining phase (DTR) immediately followed this event. During DTR, subjects either fully discontinued any kind of physical training (TC group) or performed only one resistance training and two endurance training sessions per week (RT group). Athletes were matched for body mass, training experience, and one-repetition maximum (1RM) strength in the bench press (BP) and prone bench pull (PBP) exercises and randomly assigned to either RT (n = 7) or TC (n = 7) groups. Participants reported to the laboratory on four separate occasions to assess the selected physiological and performance parameters (Fig. 1). 1RM strength, velocity at 45% 1RM load, and body composition assessments were conducted right before the start of the season (week 0; T0), at the beginning of the TAP phase (week 44; T1), the week corresponding to the world championship (week 47; T2), and finally after the DTR phase (week 53; T3). A maximal-graded exercise test on the kayak ergometer was conducted at T0, T1, and T3.

Training intervention. From week 1 to week 43, paddlers undertook an exercise program of combined strength and endurance training, under the guidance and supervision of professional canoeing coaches. Strength training was structured into four periodized cycles of 10–12 wk, during which three types of strength training phases were sequentially applied: hypertrophy (8–10 repetitions, 4–5 sets, 70%–75% 1RM loading intensity, 2-min interset rests), maximal strength (3–4 repetitions, 3–4 sets, 85%–90% 1RM, 4-min interset rests), and maximal power (5–8 repetitions, 4–5 sets, 45%–60% 1RM, 4-min interset rests). Five main exercises were used: BP, PBP, shoulder press, pull-ups, and squat. Training to repetition failure was deliberately avoided, and paddlers were constantly encouraged to perform each repetition at maximal concentric velocity. In maximal power training sessions, each set was terminated when mean velocity decreased by more than 10% of the fastest repetition's mean concentric velocity. Total strength training volume during these 43 wk amounted to 37.8 ± 2.6 h, 42 ± 3 sessions, 840 ± 60 sets, and 7560 ± 540 repetitions for hypertrophy; 41.8 ± 3.3 h, 38 ± 3 sessions, 608 ± 48 sets, and 2492 ± 197 repetitions for maximal strength; and 30.0 ± 1.1 h, 30 ± 2 sessions, 450 ± 30 sets, and 2475 ± 165 repetitions for maximal power. Endurance training was structured into three cycles of 11- to 22-wk duration. Actual endurance training volume was 249.8 ± 13.2 h at paddling speeds corresponding to 75%–90% $\dot{V}O_{2max}$, 35.7 ± 2.2 h between 90%

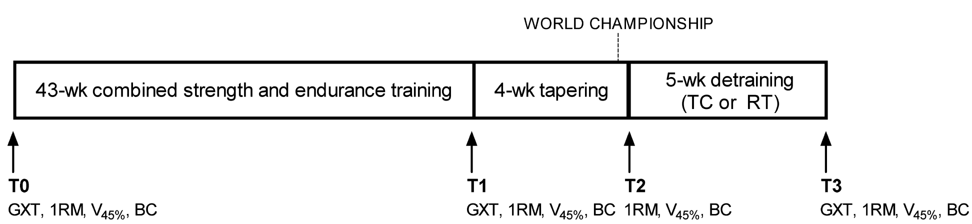

FIGURE 1—Study design including calendar of testing. TC, training cessation; RT, reduced training; GXT, maximal-graded exercise test; 1RM, one-repetition maximum strength test; $V_{45\%}$, velocity with 45% 1RM test; BC, body composition assessment.

and 105% $\dot{V}O_{2max}$, and 7.1 ± 0.6 h above 105% $\dot{V}O_{2max}$ and required athletes to paddle 60–130 km (10–15 sessions) per week.

TAP consisted of 4 wk of progressively lowering training volume while increasing intensity. During this phase, subjects completed two strength training sessions per week: a) one maximum strength session with 90%–95% 1RM (3–4RM) loads, two to four repetitions per set, and two to three sets per exercise; and b) one maximal power training session with 45% 1RM (BP and PBP) or 60% 1RM (squat) loads, five to eight repetitions, and three to four sets. Exercises during TAP were limited to BP, PBP, and squat. Total strength training volume was 2.6 ± 0.3 h, 34 ± 2 sets, and 108 ± 4 repetitions for maximal strength and 2.4 ± 0.2 h, 38 ± 5 sets, and 198 ± 34 repetitions for maximal power. Furthermore, athletes performed 5–10 endurance paddling sessions per week, in which priority was given to high-intensity exercise while progressively reducing volume up to 50% of habitual training values. Actual time devoted to endurance training during TAP was 14.3 ± 0.6 h at paddling speeds corresponding to 75%–90% $\dot{V}O_{2max}$, 4.2 ± 0.1 h between 90% and 105% $\dot{V}O_{2max}$, and 1.5 ± 0.3 h above 105% $\dot{V}O_{2max}$, in addition to the three competition days at the end of this phase.

Lastly, during DTR, the TC group fully discontinued any kind of physical training during the following 5 wk, whereas the RT group performed only one resistance training and two endurance training sessions per week. During this period, there was no control over the athletes' diet. The resistance training session performed by the RT group comprised three sets of 10 repetitions with each athlete's 70%–75% 1RM (10–12RM) load in the BP, PBP, and squat exercises, using 3-min pauses between sets. The endurance training consisted of only two 40-min moderate-intensity (~80% $\dot{V}O_{2max}$) aerobic running and paddling sessions, respectively. On the four remaining weekdays, no physical training of any kind was performed.

Testing. Testing was completed on three consecutive days: body composition and maximal-graded exercise test on the kayak ergometer (day 1), 1RM strength (day 2), and velocity at 45% 1RM assessment (day 3). The same warm-up procedures and protocol for each type of test were repeated on subsequent occasions. Testing was performed at the same time of the day (10–12 h) and under similar environmental conditions (20°C–22°C and 55%–65% humidity). The test–retest intraclass correlation coefficients for all variables measured in this study were greater than 0.93, with coefficients of variation ranging from 0.9% to 3.3%.

Body composition. Anthropometric measurements included standing height, body mass, and skinfold thicknesses (triceps brachii, subscapular, suprailiac, abdominal, anterior thigh, medial calf, supraspinale, and biceps brachii) and were performed by the same experienced investigator in accordance with guidelines from the International Society for the Advancement of Kinanthropometry (19). Body fat percentage and fat-free mass were estimated using Carter and Yuhasz's (4) formula.

Maximal-graded exercise test. After a 5-min warm-up at a speed of 9 $km{\cdot}h^{-1}$, subjects completed an incremental paddling test to volitional exhaustion on a kayak ergometer (Dansprint ApS, Denmark). The first stage was set at a speed of 11.5 $km{\cdot}h^{-1}$, and the speed increment was 0.5 $km{\cdot}h^{-1}$ each minute. Each kayaker was allowed to freely adjust his stroke rate as needed. Paddlers were strongly encouraged to give maximal effort and to complete as many stages as possible. Breath-by-breath gas analysis was conducted throughout using an automated Jaeger Oxycon Pro system (Erich Jaeger, Hoechberg, Germany) calibrated before each testing session. $\dot{V}O_{2max}$ was defined as the average of the single highest four consecutive 15-s $\dot{V}O_2$ values attained toward the end of the test.

Maximal strength and velocity at maximum power loads assessments. Testing procedures can be found elsewhere (7). Briefly, 1RM was determined in the BP and PBP exercises using free weights. These were chosen because they are the most used resistance training exercises in the sport of canoeing and are useful to assess strength and power in the opposing upper-body muscle actions of pushing and pulling. The heaviest load that each athlete could properly lift in a purely concentric action was considered to be his 1RM. On the following day, mean velocity with 45% of 1RM load ($V_{45\%}$) was assessed for both exercises. This was chosen because it has been shown to be very close to the load that maximizes the average mechanical power output for upper-body resistance exercises (3,5). Paddlers performed two sets of three repetitions with 45% 1RM, using a 5-min pause between sets. Mean velocity was determined by a linear position transducer (MuscleLab; Ergotest Technology, Oslo, Norway). The mean velocity of the three best repetitions for each athlete was registered as $V_{45\%}$.

Statistical analysis. Standard statistical methods were used for the calculation of mean values and SD. A 2 × 4 factorial ANOVA was performed to evaluate absolute changes in selected variables between time points (T0, T1, T2, and T3) and between groups (TC and RT). Effect sizes (ES) for changes in the TC and RT groups between T3 and T2 time points were calculated as the difference between the means divided by the average SD for the two groups. Significance was accepted at the $P \leq 0.05$ level.

RESULTS

No significant differences were observed at T0 between TC and RT groups in any of the following variables: body mass, fat-free mass, training experience, $\dot{V}O_{2max}$, 1RM strength in BP and PBP, or $V_{45\%}$ in BP and PBP exercises.

Body composition. Changes in body composition are reported in Table 1. Significant decreases ($P < 0.05$) were observed at T1 in sum of eight skinfolds for TC and RT groups. After TAP, a further but nonsignificant decrease in

TABLE 1. Time course of changes in body composition.

Group		T0	T1	Change T0–T1 (%)	T2	Change T1–T2 (%)	T3	Change T2–T3 (%)
TC	Body mass (kg)	85.6 ± 5.8	85.0 ± 5.4	−0.7	85.2 ± 5.8	0.2	85.2 ± 4.5	−0.2
	Fat-free mass (kg)	74.4 ± 2.7	75.9 ± 2.9	2.0	76.5 ± 2.9	0.8	74.2 ± 2.8†	−3.0
	Sum of eight skinfolds (mm)	72.3 ± 5.1	59.0 ± 4.4*	−18.4	56.1 ± 4.0	−4.9	68.9 ± 4.2†	22.8
RT	Body mass (kg)	86.7 ± 4.9	84.7 ± 5.5	−2.3	84.3 ± 4.8	−0.5	86.7 ± 4.6	2.8
	Fat-free mass (kg)	75.8 ± 2.9	76.0 ± 2.9	0.3	76.1 ± 2.7	0.2	76.2 ± 2.7‡	0.1
	Sum of eight skinfolds (mm)	70.1 ± 4.5	56.8 ± 4.3*	−19.0	53.8 ± 4.5	−5.3	66.3 ± 4.6†	23.2

Data are presented as mean ± SD. Skinfolds: triceps brachii, subscapular, suprailiac, abdominal, anterior thigh, medial calf, supraspinale, and biceps brachii.
Significant differences: when comparing * T1 with T0, † T3 with T2, and ‡ higher than TC at respective time point. $P < 0.05$.
TC, training cessation group (n = 7); RT, reduced training group (n = 7); T0, week 0, start of the season; T1, week 44, beginning TAP phase; T2, week 47, world championship week; T3, week 53, right after detraining.

sum of eight skinfolds was observed in both TC (−4.9%) and RT (−5.3%) groups when comparing T2 with T1. At T3, no significant changes were observed in body mass in any group compared with T2, whereas significant increases ($P < 0.05$) were observed in sum of eight skinfolds for both TC (22.8%, ES = 3.12) and RT (23.2%, ES = 2.75). After DTR, no significant differences between groups were found in the magnitude of changes in sum of eight skinfolds, whereas significant group × time interaction was observed for fat-free mass, with a significantly larger ($P < 0.05$) magnitude of decrease for TC (−3%, $P < 0.05$) compared with RT (−0.1%, NS).

Muscle strength. Significant increases ($P < 0.05$) in 1RM strength and $V_{45\%}$ were observed in BP and PBP exercises for both TC and RT groups when comparing T1 with T0 (Fig. 2A). At T2, after the TAP phase, no significant changes were observed in 1RM strength or $V_{45\%}$ values for any group. After DTR, significant group × time interaction was observed for 1RM strength, with a significantly larger ($P < 0.05$) magnitude of decrease for the TC group (−8.9% and −7.8%, $P < 0.05$, ES = −1.81 and −1.98, respectively, for BP and PBP) than that observed for the RT group (−3.9% and −3.4%, NS, ES = −0.67 and −0.87). Decreases in $V_{45\%}$ in BP and PBP exercises after DTR were larger for TC (−12.6% and −10.0%, ES = −2.15 and −1.67, respectively) than those observed for RT (−9.0% and −6.7%, ES = −1.67 and −0.67). No significant differences between groups were observed in the magnitude of changes in $V_{45\%}$ (Fig. 2B).

Maximal aerobic power. At T1, significant increases ($P < 0.05$) in $\dot{V}O_{2max}$ were observed for both TC (8.8%, from 63.5 to 69.1 mL·kg^{-1}·min^{-1}) and RT (8.3%, from 63.2 to 68.5 mL·kg^{-1}·min^{-1}) when comparing with T0. After DTR, significant group × time interaction was observed for $\dot{V}O_{2max}$ with a significantly larger ($P < 0.05$)

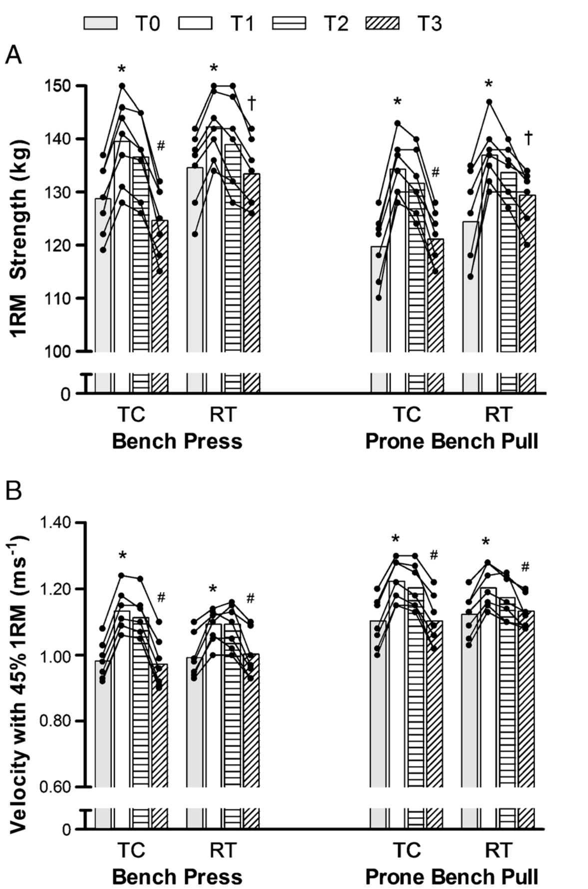

FIGURE 2—Time course of changes in one-repetition maximum (1RM) strength (A) and velocity attained with 45% 1RM (B) in the bench press and PBP exercises. TC, training cessation group (n = 7); RT, reduced training group (n = 7). Data are presented as mean ± SD. Significant differences: when comparing *T1 with T0, #T3 with T2, and †higher than TC at respective time point ($P < 0.05$).

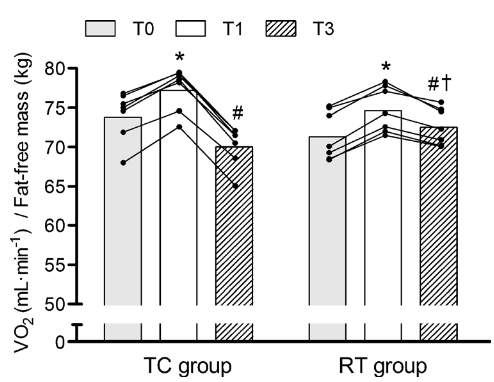

FIGURE 3—Time course of changes in $\dot{V}O_{2max}$ values adjusted to account for fat-free mass. TC, training cessation group (n = 7); RT, reduced training group (n = 7). Data are presented as mean ± SD. Significant differences: when comparing *T1 with T0, #T3 with T2, and †higher than TC at respective time point ($P < 0.05$). Changes from T0 to T1 and from T1 to T3 for both groups are reported in parentheses.

magnitude of decrease for TC (−11.3%, from 69.1 to 61.3 mL·kg^{-1}·min^{-1}, $P < 0.05$, ES = −2.36) compared with RT (−5.6%, from 68.5 to 64.6 mL·kg^{-1}·min^{-1}, NS, ES = −1.28). The time course of changes in $\dot{V}O_{2max}$ values, adjusted to account for fat-free mass, is shown in Fig. 3.

DISCUSSION

This study examined the effects of a precompetition taper (4 wk) and subsequent detraining period (5 wk) on neuromuscular, body composition, and endurance performance changes in a group of world-class athletes whose sport (i.e., Olympic sprint kayaking) requires very high levels of both muscle strength and aerobic power. We have recently reported (7) that a periodized training program can be effectively used for simultaneously developing the different fitness components of strength and aerobic endurance in elite kayakers, yet there is a paucity of literature on the effects that typical tapering and/or short-term detraining periods could have on neuromuscular and performance markers for this type of top-level athletes. The main findings of the present study were that a period of 5 wk of markedly RT in a group of elite athletes seems effective for minimizing the large declines in strength levels that take place by completely stopping physical training for an equivalent period as well as for maintaining fat-free mass close to habitual levels. However, velocity at 45% 1RM, although slightly better retained in the RT compared with the TC group, was more difficult to maintain when no specific training stimuli were provided. The 4-wk taper was effective for maintaining maximal strength and $V_{45\%}$ but not to further increase them. These data indicate that although both the RT and the TC groups decreased performance between T2 and T3, TC induces larger neuromuscular declines than those found after an RT strategy.

With the ever-increasing number of competitions and rigorous demands of modern sport at the elite level, experiencing an excessive loss of neuromuscular function during the layoff between seasons could have undesired detrimental consequences for the athletes' performance in subsequent training cycles. Furthermore, the reduced volume of training usually performed in the preceding precompetition tapering could add up to the aforementioned loss of physical conditioning. For top-level athletes, the present investigation has shown that significant strength is lost (8.9% and 7.8% declines in 1RM values for BP and PBP, respectively) after 5 wk of complete TC. By contrast, performing only one weekly resistance training session allowed the RT group to reduce by more than half the magnitude of maximal strength declines (3.9% for BP and 3.4% for PBP) (Fig. 2A). The nonsignificant loss of maximal strength after TAP (~2% for both groups and exercises) can likely be explained by the greatly reduced volume of strength training during the full 4-wk duration of the taper by these already highly conditioned and muscular athletes. The 1RM strength decreases observed for the TC group after DTR were similar to those found by other authors in experienced, strength-trained athletes after 4-wk detraining: 10% for squat (10), 9% for BP, and 6% for half-squat (17). Longer periods of TC (8 wk) seem to result in more pronounced declines in strength as found by Häkkinen et al. (9), who reported 11.6% and 12.0% decreases for squat and knee-extension exercises, respectively. However, after shorter periods of detraining, muscle strength declines were minimal (13,14).

$V_{45\%}$ experienced significant reductions after the 5 wk of detraining but remained unchanged after TAP. It seems therefore that the tapering period used in the present study was effective for maintaining velocity at maximal power loads levels but not to further increase their magnitude, a finding in agreement with that reported by Izquierdo et al. (17) after a similar 4-wk taper. In the TC group, $V_{45\%}$ decreased by 12.6% and 8.3% in the BP and PBP exercises, respectively (Fig. 2B). Although somewhat lower, these declines were also notably significant (9.2% for BP and 6% for PBP) for $V_{45\%}$ in the RT group. The finding that detraining results in a larger reduction in muscle power than maximal strength has already been reported (17,18,26) and suggests that very specific stimuli (i.e., "power training") may be necessary to maintain maximal power levels in these highly trained elite athletes. Thus, it can be further speculated that muscle power may be much more rapidly lost than maximal strength in elite athletes. These detraining-induced declines in neuromuscular performance detected in top-level athletes are similar to those described by Fry et al. (6), who also found significant decreases in weight-trained athletes at the neuromuscular level after inducing overtraining. These data seem to emphasize the importance of establishing the optimal training load in each training phase when devising effective periodization schemes for highly trained athletes.

The increases in sum of eight skinfolds (~23%) observed after DTR for both groups are larger than those described in the literature for well-trained athletes after 2–6 wk of TC (Table 1) (13,17,28). These differences may be attributable to several factors: the lacking (TC) or insufficient (RT) aerobic endurance stimuli during the detraining period, the very low levels of fat registered for the kayakers at the major event of the season (T2), and the absence of control over the athletes' diet during DTR. The observed fat-free mass losses of 3% after TC are in line with results from previous studies (1,9) that detected decreased muscle mass after 6–8 wk of training stoppage. Unlike the TC group, fat-free mass remains unchanged in the RT group (Table 1), thus supporting the use of some form of maintenance training during periods of detraining.

Of considerable interest was the fact that declines in $\dot{V}O_{2max}$ after DTR were much lower for the RT group (−5.6%), which performed only two maintenance endurance exercise sessions per week, than for the TC group (−11.3%), which completely discontinued endurance training for 5 wk. When expressing $\dot{V}O_{2max}$ values relative to fat-free mass (Fig. 3), the results similarly showed the effectiveness of the RT program. This finding may suggest

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the convenience of maintaining some reduced endurance stimuli during transition periods in an attempt to minimize losses in endurance performance.

In conclusion, our results support previous research showing that short-term TC results in larger decreases in muscle strength and power in resistance- and endurance-trained top-level athletes compared with an RT approach. Moreover, muscle power appears particularly susceptible to detraining in highly conditioned athletes, being lost at a faster rate than maximal strength. These results may suggest the need of a minimal maintenance program of RT to avoid excessive declines in neuromuscular function and fat-free mass in cases where a prolonged break (longer than 2–3 wk) from training is required.

No funding was received for this work from any of the following organizations or any other institution: National Institutes of Health, Wellcome Trust, and Howard Hughes Medical Institute.

The authors thank personnel from the High-Performance and Sport Science Research Center (CARICD) in Madrid for their excellent technical help with laboratory apparatus and medical assistance to the athletes. The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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