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ORIGINAL INVESTIGATIONS

Physiological and performance responses to overtraining in elite judo athletes

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ABSTRACT

CALLISTER, R., R. J. CALLISTER, S. J. FLECK, and G. A. DUDLEY. Physiological and performance responses to overtraining in elite judo athletes. *Med. Sci. Sports Exerc.*, Vol. 22, No. 6, pp. 816–824, 1990. To determine the effect of large and sudden increases in training volume on performance characteristics and the feasibility of using overtraining syndrome symptoms to monitor performance changes, 15 elite judo athletes were examined through 10 wk of training. Athletes performed their regular regimens of resistance (3 $d \cdot wk^{-1}$), interval (2 $d \cdot wk^{-1}$), and judo (5 $d \cdot wk^{-1}$) training in weeks 1–4. Interval and resistance training volumes increased by 50% in weeks 4–8 and returned to baseline in weeks 9–10. Judo training volume was unchanged in weeks 1–8 but increased by 100% in weeks 9–10. Assessments were made in weeks 2, 4, 8, and 10. Isokinetic strength of elbow and knee extensors and flexors increased significantly from weeks 2 to 4 (3–13%), was unchanged from weeks 4 to 8, and decreased significantly (6–12%) from weeks 4 to 10. Total time for 3 × 300 m intervals increased ($P < 0.05$) between weeks 2 and 4 and between weeks 4 and 8, while total time for 5 × 50 m sprints decreased ($P < 0.05$) from weeks 8 to 10 (<2%). Body fat percentage decreased ($P < 0.05$) from weeks 2 to 10. Body weight, submaximal and maximal aerobic power, resting (sleeping) systolic and diastolic pressures, resting (sleeping) submaximal and maximal heart rates, exercising blood lactate levels, and vertical jump performance did not change significantly with increases in training volume. These results suggest that 6 wk of overtraining may affect some but not all aspects of performance and that performance may be affected before symptoms of the overtraining syndrome appear.

STALENESS, TRAINING VOLUME, ISOKINETIC, STRENGTH, HEART RATE, BLOOD PRESSURE

Concern for the impact of overtraining on athletic performance has existed for many years (2,20,21). Despite this interest, many questions relating to overtraining remain unanswered. Among these is the relationship between effects on performance and the manifestation of the so-called overtraining syndrome symptoms.

Overtraining is a general term used to describe both the process of training excessively and the fatigue states that may develop as a consequence (17,19). The indiscriminant use of this term has led to ambiguity and at times misunderstandings (2,17,19). Therefore, it is necessary to define our use of overtraining terms. Following the suggestions of recent reviewers (17,19), we define overtraining as the process of performing an abnormally large quantity of intense physical training. Thus, overtraining is a stimulus, and one consequence may be detrimental effects on athletic performance.

The overtraining syndrome or staleness (7,10, 14,21,23) refers to the final stage in a proposed continuum of increasingly severe, chronic fatigue states that may develop as a result of overtraining. This syndrome is characterized by many physiological and psychological symptoms (1,2,5,7,14,20,21,23) as well as decreased athletic performance. The physiological symptoms include loss of body weight and body fat, increased heart rates at rest and during submaximal exercise, changes in resting blood pressure, increased risk of illness and injury, and chronic muscle soreness (2,6,7,15,18,20,21). Decrements in aerobic power and muscular strength have also been reported (8,23,24). The effectiveness of these characteristics in conjunction with psychological symptoms for the diagnosis of this syndrome appears to be well established (1,2,5,15,17–19,22).

Unfortunately, there is no widely accepted terminol-

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ogy to describe other overtraining states or phenomena, and, therefore, they have tended to be ignored (10). For elite athletes, assuming that the overtraining syndrome is the only consequence of overtraining of any significance may not be prudent. Of greater importance may be the possibility that earlier stages in a developing overtraining phenomenon may also adversely affect athletic performance. One purpose of this study was to examine the effect of overtraining on performance.

Detection of early or intermediate stages in the development of an overtraining state such as staleness has been hypothesized but poorly characterized (10,17). It is unclear, for example, whether overtraining can adversely affect performance without the development of these overtraining symptoms or whether these symptoms can occur without detrimental effects on performance. Failure to improve performance despite an increased training stimulus may also be an undesirable response to overtraining (2). Prevention of this overtraining syndrome or any adverse effect on performance is obviously desirable. It has been suggested that the symptoms of the overtraining syndrome could be monitored throughout training to detect early stages (2,19) and thus provide a marker for intervention. If these symptoms are to be used as indices for the prevention of overtraining effects, it is necessary to establish the time course relationship between the development of performance decrements and these symptoms. This was the second goal of this study.

Overtraining has been recognized as a potential cause of compromised athletic performance for over 50 yr (20,21), yet there have been few attempts to investigate the responses to overtraining experimentally (17). Most studies of overtraining have been anecdotal (2,21), cross-sectional (1,22,23), or of short duration (4,6,7,16). Longitudinal studies are necessary to determine the feasibility of predicting the development of overtraining consequences by monitoring these symptoms or other indices (16,19). There have been few studies, usually of short duration, that have monitored these symptoms during moderate training or overtraining (4,6,7,16,19). In particular, there have been few investigations that have studied the effects of several weeks of intense physical training on these variables in elite athletes, who are considered to be at the greatest risk of overtraining (2,14).

Although recent studies of overtraining have examined endurance sports (1,4,6), indications are that any athlete can overtrain (24). Traditionally, athletes in sports where strength, speed, and coordination are important, particularly combative sports (15,24) such as judo, have been considered at higher risk. Overtraining has rarely been examined in a longitudinal manner in non-endurance sports (19). These athletes typically perform large quantities of intense anaerobic exercise in training, training often implicated as contributing to the development of overtraining effects. Large and sudden increases in training volume are also said to increase the risk of detrimental effects on performance (2).

This study was designed to investigate the responses of elite judo athletes to 4 wk of regular training and 6 wk of overtraining. Training volume increased twice, after 4 and 8 wk of training. This enabled us to examine the impact of increasing the volume of high intensity training on different aspects of performance in elite athletes who were already performing substantial quantities of intense anaerobic exercise. Performance variables, including strength and aerobic and anaerobic power, were examined. The athletes were monitored for symptoms characteristic of the overtraining syndrome, such as elevations in heart rate during rest (sleep) or submaximal exercise, changes in resting (sleeping) blood pressure, loss of body weight or body fat, and changes in the oxygen uptake and blood lactate responses to exercise. Measurements were taken throughout the 10 wk period to determine the feasibility of using these symptoms to reflect or predict changes in performance.

METHODS

Subjects. Fifteen national or international level judo players (eight men and seven women) volunteered to participate in the study. Several characteristics of these athletes are presented in Table 1. Prior to the study they had competed at the U.S. Judo Nationals followed by 1 wk of rest. All subjects were informed of possible risks involved and gave their written consent.

Experimental design. Subjects were followed through 10 wk of training divided into three phases of increasing total training volume (Fig. 1). Phase I (weeks 1–4) was considered a baseline phase and subjects performed their regular regimens of judo and interval and resistance training. In phase II (weeks 5–8) the volumes of interval and resistance training were increased by 50% while maintaining training intensity. In phase III (weeks 9–10) interval and resistance training volumes were reduced to phase I levels while judo training volume doubled (100% increase). The total quantity of training was greatest in phase III. Tests to examine the responses to training were performed in weeks 2, 4, 8, and 10. Psychological and other physiological variables were also assessed, and the data will be reported elsewhere.

Training. Judo training sessions were normally 2½ h in duration, consisted of judo specific skills and drills, mat work, and randori (fighting practice), and were performed 5 $d \cdot wk^{-1}$ (one per day in weeks 1–8, two per day in weeks 9–10). Randori bouts, each lasting 3 min with 30 s rest between bouts, were performed for a minimum of 1 h per session.

TABLE 1. Characteristics of the subjects.

	Age (yr)	Height (cm)	Weight (kg)	Fat (%)	$\dot{V}O_2$	U.S. Rank
Males ($n = 8$)	25.6 ± 1.5	179.9 ± 2.5	91.5 ± 2.7	10.8 ± 1.9	53.2 ± 1.4	6.3 ± 0.8
Females ($n = 7$)	24.0 ± 1.9	159.3 ± 1.6	56.3 ± 0.9	15.8 ± 1.2	51.9 ± 0.8	3.3 ± 0.7
Combined ($n = 15$)	24.9 ± 1.2	170.3 ± 3.1	75.1 ± 2.7	13.1 ± 1.3	52.6 ± 0.8	4.9 ± 0.7

Values are mean ± SE. Fat (%): percent body fat. $\dot{V}O_2$: peak oxygen uptake, $ml \cdot kg^{-1} \cdot min^{-1}$. U.S. Rank: rank of player in U.S. based primarily on performance in major U.S. tournaments, as determined by Judo Governing Body.

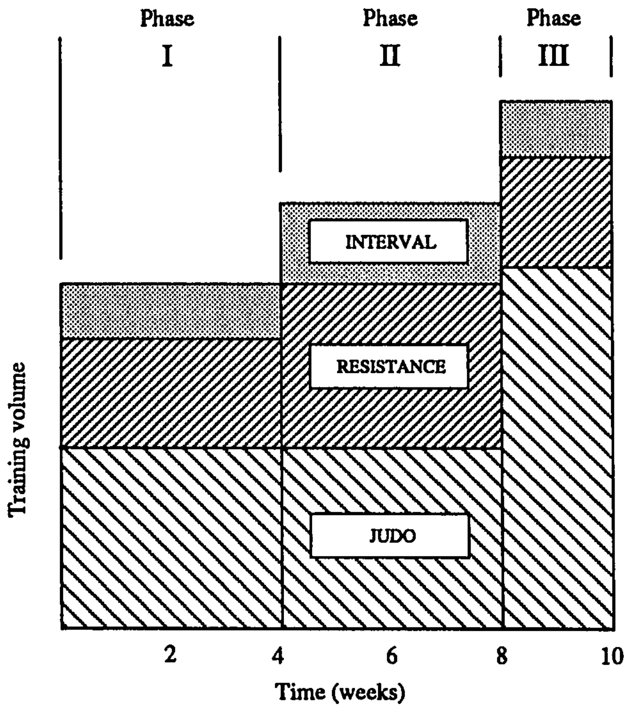

Figure 1—Schematic representation of the changes in training volume for each component of training: interval, resistance, and judo. Interval and resistance training increased by 50% in phase II. Judo increased by 100% in phase III. Total training volume increased in phase II and further in phase III.

Interval training consisted of running on a 400 m track or cycling on an ergometer twice per week. Cycle intervals were performed against the maximal resistance that could be maintained at 90 rpm for 30 s. Interval workouts were as follows:

	Phase I	Phase II	Phase III
Run:	4 × 200 m	6 × 200 m	8 × 100 m
	4 × 200 m	6 × 200 m	6 × 50 m
	8 × 100 m	12 × 100 m	6 × 50 m
Cycle:	4 × 40 s	6 × 40 s	8 × 20 s
	4 × 40 s	6 × 40 s	6 × 15 s
	8 × 20 s	12 × 20 s	6 × 15 s

Five minutes of rest were allowed between each set of intervals. Rest periods between repetitions were 2 min (200 m or 40 s bouts), 1 min (100 m or 20 s), and 30 s (50 m or 15 s). Exercise/rest ratios were approximately 1:3.

Resistance workouts were performed 3 $d \cdot wk^{-1}$ and consisted of either a circuit or conventional weight program, whichever the athlete normally performed. Exercises in the conventional program consisted of power cleans, squats, deadlifts, and bench press (free weights; four to five sets of five repetitions per exercise in phase I) and leg curls, lat pulls, arm curls, and wrist curls (three sets of ten repetitions per exercise in phase I). Exercises for the circuit program consisted of leg press, leg extensions, leg curls, military press, bench press, lat pulls, arm curls, upright rows, and wrist curls (three sets of ten repetitions per exercise in phase I). Pull-ups, dips, hyperextensions, and inclined sit-ups, all performed with body weight plus added resistance, were performed to failure (three sets in phase I) by all subjects. Subjects performed repetition maximum loads in both programs and continually strived to increase the loads, regularly training to failure during some of their sets. Two of the investigators were present at each training session to ensure that the training effort was sustained. The number of sets was increased by 50% in phase II (e.g., seven sets of five reps; five sets of ten reps), while loads remained at repetition maximum and repetitions per set remained essentially the same. Training sessions in phase III were the same as in phase I. Loads and repetitions were recorded and summed to determine the total quantity of training performed by each subject in each session. Warm-up sets were not included. Daily totals were averaged for each phase of training.

On Saturdays, training was less formal and consisted of either an additional judo practice or a game activity such as soccer. On Sundays, all training was left to the discretion of the individual.

Testing. Tests were performed on the same day of each test week and before daily training in weeks 2, 4, 8, and 10 (Fig. 2).

Concentric isokinetic strength changes were assessed in both knee and elbow extensors and flexors of the right limbs of the subjects essentially as described previously (3). Subjects were tested at five angular velocities, 1.05, 1.57, 3.14, 4.19, and 5.24 $rad \cdot s^{-1}$ (60, 90, 180, 240, and $300° \cdot s^{-1}$), using a Cybex II dynamometer and data reduction computer (Cybex Division of Lumex, Ronkokoma, NY). Subjects were stabilized by Velcro straps on the seated bench (lower limb) or upper body exercise table (upper limb) to minimize extraneous movements. Following a brief warmup, subjects performed three trials at each speed, with 1 min rest between velocities. The ranges of motion for move-

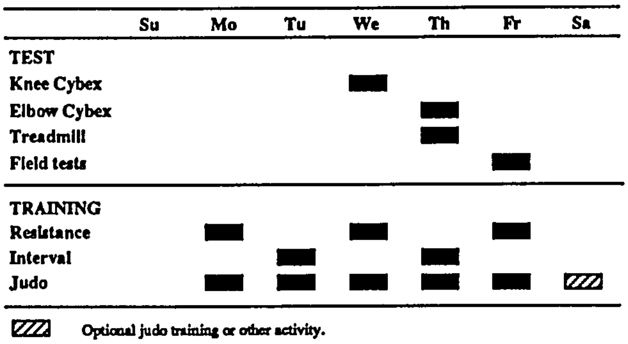

Figure 2—Sequence of testing and training in test weeks.

ments, controlled by a range limiting device, were 1.57 and 2.09 rad (90 and 120°) about the knee and elbow joints, respectively. Peak angle specific torque was recorded 0.52 rad (30°) before full extension (0°) and full flexion (90 or 120°) for both upper and lower limbs. Calibration of the dynamometer and recording systems was checked prior to each test session.

Peak and submaximal oxygen consumptions were assessed during a multistage treadmill test. Subjects ran for 4 min at four submaximal workloads, with 30 s rest between stages, and then performed an incremental load max test at constant speed with a 2% grade increase each min until volitional exhaustion. Oxygen uptake was determined using a Gould 2900 system (Gould Inc., Dayton, OH). Values for the last minute of each submaximal stage and peak $\dot{V}O_2$ were recorded. Heart rate was monitored continuously via telemetry and values for the last 30 s of each stage recorded. Fingertip blood samples were taken 5 min post-exercise and blood lactate values determined using a Yellow Springs 23L Lactate Analyzer (Yellow Springs, OH). Skinfold measurements were taken prior to the treadmill test in weeks 2, 8, and 10 and body fat percentages calculated (11,12).

As judo performance cannot be easily quantified, three simple, reliable field tests were selected to assess different components of anaerobic performance. Vertical jump was determined using the Vertex (Palo Alto, CA) jump stand. Standing reach was measured as the height reached with one arm fully extended while both heels remained on the ground. Subjects jumped with both feet following a one step approach. The maximal hand height attained with one arm fully extended was determined. Vertical jump height was the difference between maximal hand height and standing reach. The best of three trials was recorded. After 5 min of rest, subjects performed 5 × 50 m sprints separated by 45 s rest intervals. Sprints were timed using electronic timing lights placed on the 0 and 50 m marks, and the sum of the times for the five sprints was recorded. Following 15 min of rest, subjects ran 3 × 300 m intervals separated by 2 min of rest. Each interval was timed individually by stopwatch and the sum of the three intervals recorded. Tests were performed in this order to minimize the impact of residual fatigue on the subsequent test.

Elevations in resting heart rate and changes (increases or decreases) in blood pressure are frequently mentioned symptoms of the overtraining syndrome. There are many constraints on obtaining truly resting values during the day when the athletes are so active. If only one or two measurements are made, reliability may be questioned. Ambulatory blood pressure monitors (Del Mar Avionics, Del Mar, CA) were used to determine nighttime values as a better index of resting values. These enabled determinations of resting values based on numerous measurements and eliminated the possibility of values being elevated due to acute responses to bouts of exercise. Monitors were worn overnight by 12 of the 15 subjects. Twelve subjects (six males and six females) wore the monitors in weeks 2 and 8. Of these 12, six subjects (two males and four females) wore the monitors a third time in week 10. Blood pressure and heart rate were recorded every 30 min between midnight and 7:00 a.m. to determine these resting values (13).

During judo practices, fingertip blood samples were drawn randomly in the 30 s intervals between randori bouts, and blood lactate values were determined using the same methods previously described. Heart rates were also monitored immediately following randori bouts via carotid artery palpation. Mean values of heart rate and lactate values were used as estimates of judo training intensity.

Data were analyzed by one- and two-way repeated measures MANOVA. Tukey *post hoc* tests were performed when appropriate. The alpha level for statistical significance was set up at $P < 0.05$.

RESULTS

Daily resistance training volume averaged (mean ± SE, kg) 9010 ± 815 (phase I), 13,400 ± 1170 (phase II), and 9175 ± 785 (phase III). Interval runners maintained intensity above 90% of their best interval times throughout training. Interval cyclists trained at constant resistance and maintained pedal frequency above 80 rpm. The content of judo practices was consistent throughout phases I and II, with an increased emphasis on mat work and randori in phase III. During judo sessions, blood lactate values averaged 8.9 ± 0.5 $mmol \cdot l^{-1}$ (mean ± SE), and heart rates averaged 184 ± 3 bpm, values which were 114% and 96% of treadmill maximums, respectively.

Isokinetic force output increased significantly ($P < 0.05$) during phase I (weeks 2–4) in all muscle groups tested and at all test velocities (Fig. 3). Increases ranged from 3 to 13%. There were no significant changes in any muscle group in phase II (weeks 4–8). Force output

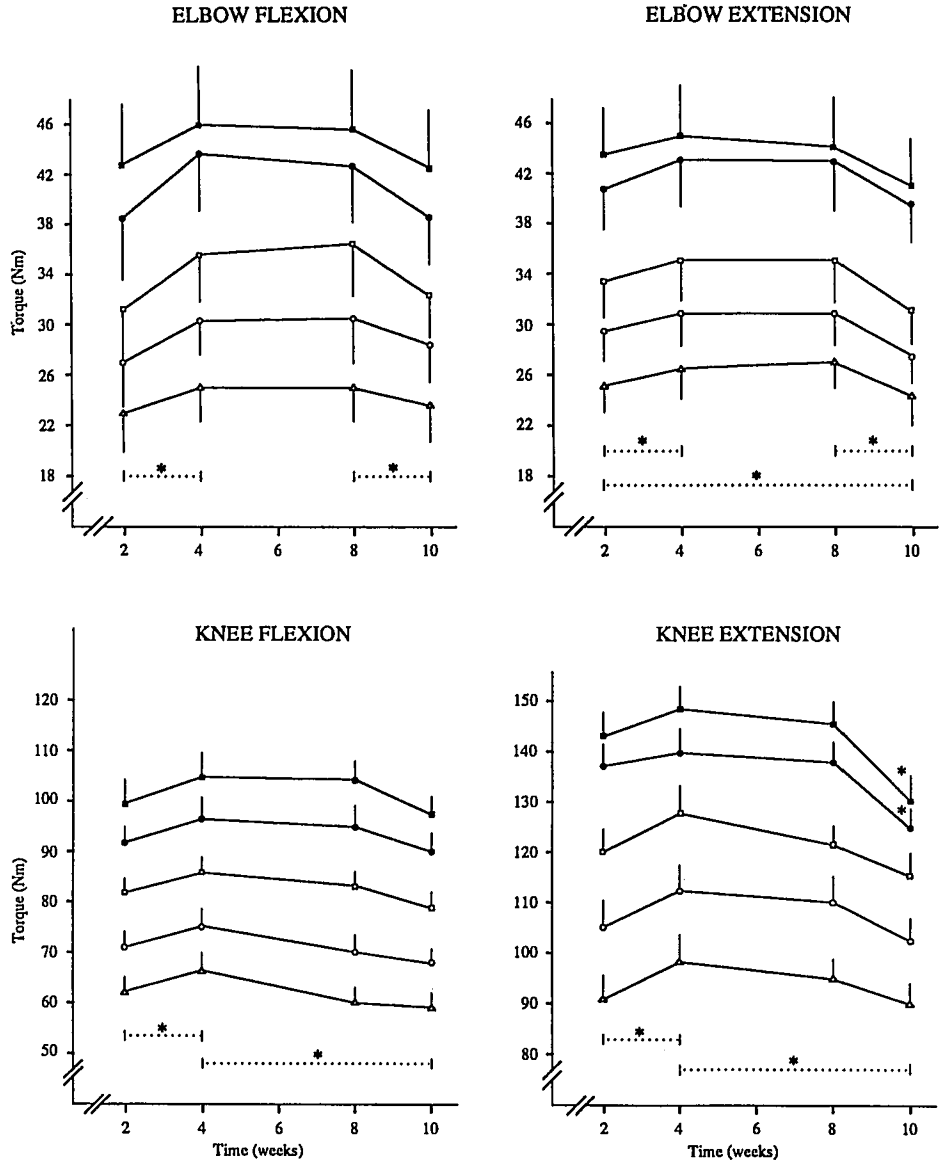

Figure 3—Peak angle specific torque measured at five angular velocities in elbow and knee flexors and extensors in weeks 2, 4, 8, and 10. Angular velocities ($rad \cdot s^{-1}$) were: ■, 1.05; ●, 1.57; □, 3.14; ○, 4.19; and △, 5.24. |*|, significant difference ($P < 0.05$) across time period indicated independent of test velocity. *Significant difference ($P < 0.05$) from week 2 at specific velocity. Values are mean ± SE.

of the elbow flexors and extensors decreased (6–12%) during phase III (weeks 9–10) compared to the end of both phase I (week 4) and phase II (week 8). Force output of knee flexors and extensors also decreased in phase III as week 10 values were significantly ($P < 0.05$) lower (6–12%) than values at the end of phase I (week 4). Comparisons between week 2 (phase I) and week 10 (phase III) indicate significantly ($P < 0.05$) lower values for elbow extensors at all velocities (4–8%) and knee extensors at slower speeds (8.5%). Thus, concentric isokinetic strength increased during phase I (regular training), failed to continue to improve in phase II (increased resistance and interval training), and decreased, even below initial values in some muscle groups, in phase III (greatest training volume).

Total 300 m interval times increased significantly ($P < 0.05$) during both phase I (1.6%; weeks 2–4) and phase II (1.2%; weeks 4–8) and did not change in phase III (Fig. 4). Thus, 300 m interval times became slower over the course of the study. There were no changes in total 50 m sprint time in phases I and II (weeks 2–8), but there was a significant improvement (<2%) in phase III (weeks 8–10; Fig. 4). Vertical jump was unchanged throughout the study.

Body weight did not change but body fat percentage decreased ($P < 0.05$) from week 2 to week 10 (Table 2). Submaximal and peak $\dot{V}O_2$ were unchanged by training, as were submaximal and maximal heart rates. Blood lactate levels following the treadmill test (5 min post-exercise) were unchanged. No changes were observed in mean resting (overnight) systolic or diastolic pressure or resting heart rate (Table 3). Values are presented for the six subjects who wore the monitors three times, followed by the values for all 12 subjects who wore monitors during weeks 2 and 8.

There were no differences in the responses to the tests due to gender or due to the type of interval or resistance training performed.

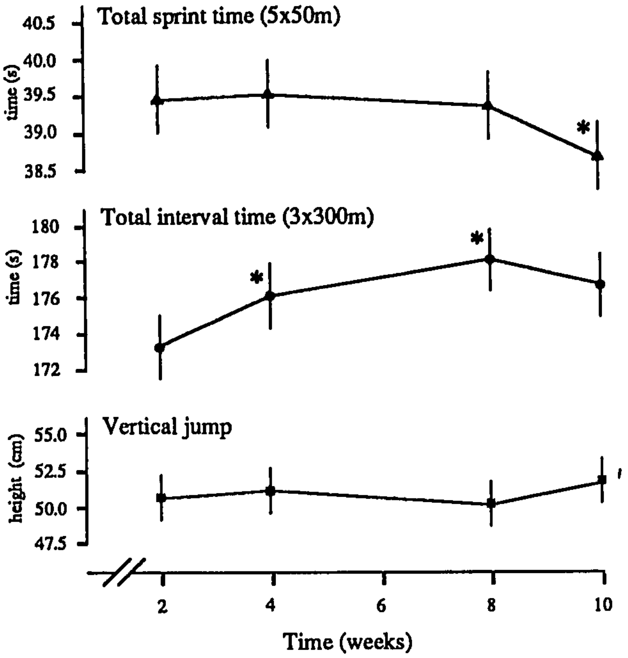

Figure 4—Performance in field tests in weeks 2, 4, 8, and 10. Values are mean ± SE. *Significantly different ($P < 0.05$) from week 2.

TABLE 2. Responses of physical and physiological variables to training.

Week	2	4	8	10
Body fat (%)	13.1 ± 1.3		12.7 ± 1.4	12.2 ± 1.3*
Body weight (kg)	74.7 ± 5.7	75.3 ± 5.6	75.0 ± 5.6	72.2 ± 5.6
$\dot{V}O_2$ (l·min^{-1})				
Stage 1	2.77 ± 0.18	2.71 ± 0.17	2.70 ± 0.16	2.76 ± 0.18
Stage 2	3.00 ± 0.20	2.94 ± 0.20	2.98 ± 0.19	3.03 ± 0.20
Stage 3	3.20 ± 0.22	3.15 ± 0.21	3.17 ± 0.21	3.22 ± 0.21
Stage 4	3.39 ± 0.24	3.33 ± 0.22	3.34 ± 0.22	3.40 ± 0.23
$\dot{V}O_2$ peak	3.98 ± 0.31	3.90 ± 0.27	3.81 ± 0.25	3.93 ± 0.26
Heart rate (bpm)				
Stage 1	153 ± 3	154 ± 3	155 ± 4	155 ± 3
Stage 2	163 ± 3	165 ± 3	164 ± 4	166 ± 3
Stage 3	172 ± 3	174 ± 3	171 ± 3	172 ± 3
Stage 4	179 ± 3	180 ± 3	178 ± 3	178 ± 3
HR_{max}	191 ± 2	192 ± 3	189 ± 2	191 ± 2
Blood lactate (mmol·l^{-1}) (peak lactate)	7.8 ± 0.4	7.7 ± 0.3	6.9 ± 0.4	7.7 ± 0.7

Values are mean ± SE.
* Significantly ($P < 0.05$) different from week 2.

TABLE 3. Effects of training on nighttime (resting) blood pressure and heart rate.

($N = 6$)	Week 2	Week 8	Week 10
Systolic pressure (mm Hg)	114 ± 6	113 ± 5	112 ± 4
Diastolic pressure (mm Hg)	65 ± 2	64 ± 2	65 ± 3
Heart rate (bpm)	54 ± 2	51 ± 3	53 ± 4
($N = 12$)	**Week 2**	**Week 8**	
Systolic pressure (mm Hg)	118 ± 3	116 ± 3	
Diastolic pressure (mm Hg)	67 ± 2	67 ± 3	
Heart rate (bpm)	55 ± 2	53 ± 3	

Values are mean ± SE.

DISCUSSION

Manifestation of many of the characteristic symptoms of the overtraining syndrome allows diagnosis of the syndrome (1,2,5,17,19). The failure to observe manifestations of these symptoms in this study suggests that these athletes did not fully develop the overtraining syndrome. This may not be unexpected in a group of elite athletes who are routinely required to overtrain in preparation for competition, and their attainment of elite status may, in part, reflect their ability to tolerate this quantity of training when performed for relatively short periods of time.

We do, however, suggest that these athletes suffered adverse effects on performance due to the training performed in this study without manifestation of these symptoms. As has been suggested previously (10), this may occur as part of a developing overtraining phenomenon for which there is no adequate or widely accepted terminology.

First, we wish to establish that these athletes were overtraining. Admittedly, any description of training as overtraining reflects a subjective evaluation, but a review of the training performed in this study leaves little doubt that these athletes were training at or near their maximum capacity. These athletes trained 4–7 $h \cdot d^{-1}$ (phases I–III), 6 $d \cdot wk^{-1}$, at extremely high intensities. Resistance training volumes increased 49% between phases I and II and were comparable to the average daily training volumes of elite weight lifters (9). Yet this was only one component of these athletes' training. Interval workout intensities were maintained at 90% of phase I levels despite the increase in training volume. Blood lactate levels were higher following randori bouts than following the treadmill test and, together with near maximal heart rates observed during judo sessions, indicate sustained high intensity workouts. These athletes were performing a large quantity of high intensity training in phase I and a substantially larger quantity during phases II and III. Thus, it appears justified to conclude that these athletes were overtraining, i.e., performing an extremely large quantity of intense training that posed a serious risk of compromising performance. In addition, training changes were initiated rapidly rather than phased in gradually, increasing the risk of adverse consequences (2).

Second, we wish to examine the impact of this training on performance as it is this aspect of overtraining that is of prime importance to elite athletes. One limitation of studying a sport such as judo is that the impact of training on sport specific performance is difficult to quantify. We have only the coach's subjective evaluation that performance during judo training sessions was diminished. Thus, a number of different aspects of performance were examined objectively to ascertain an overtraining response, and some aspects of performance were adversely affected.

Isokinetic strength improved when training volume was lowest, suggesting an effective training stimulus during phase I, although total 300 m time did become slightly slower during this time. In phase II, as training volume increased, we observed a failure to make further gains in strength and a further increase in 300 m times. Both of these responses suggest an adverse training effect. The decrease in isokinetic strength in all four muscle groups and at all test velocities in phase III suggests that the greatest impact of overtraining was felt in this phase. This may have been due to a) the cumulative effects of overtraining fatigue from phases II and III, b) the further increase in training volume as the total quantity of training performed was greatest in phase III, or c) a combination of these effects. It may also suggest that the total quantity of training and the total duration of overtraining were more critical factors than the specific type of training performed.

Although repetition maximum strength performance during resistance training did not decrease noticeably in phase III, there was also no tendency to show improvement despite the reduction in resistance training volume. This may be indicative of an adverse overtraining response. The difference between this failure to improve and the isokinetically determined strength decreases may represent a difference between the effect of this overtraining on maximal force output and repeated muscular effort or muscle endurance.

Not all aspects of performance were affected simultaneously or to the same degree. Vertical jump ability was unaffected throughout the study. Total 50 m interval performance was unchanged in phases I and II and tended to improve in phase III even though total training volume was at its greatest. The improvement in 50 m performance may have reflected the change to shorter interval training distances, but interestingly this improvement was not limited by the increase in total training volume. Some aspects of performance, such as strength, may be more sensitive to the acute affects of overtraining fatigue than others.

Many of the symptoms that have traditionally been used to diagnose the overtraining syndrome were monitored in this study. One purpose was to determine whether the state of staleness could be induced in this relatively short period of time. As stated earlier, insufficient symptoms developed to draw this conclusion. A second goal was to examine the feasibility of using any of these symptoms for the detection of overtraining (2,7,16,18,20). In previous studies where changes were observed, assessments were usually based on one or two daily measurements. In this study, by using ambulatory monitors, the values were determined from 12 measurements over a 7 h period during prolonged rest (sleep). No changes were observed in these variables. Although we feel that this is a more reliable measure of resting values, it is possible that daytime values were elevated while nighttime values were not. No previous studies of overtraining have examined resting values in this manner. Oxygen uptake and heart rates at submaximal exercise intensities may increase in response to overtraining, while maximal oxygen uptake and blood lactate values may decrease (4,20). No significant changes were observed in this study. This does not mean that these variables are ineffective indicators of staleness but suggests that they are symptoms that are manifested too late in the development of an overtraining state to allow effective prevention of some effects on performance.

Body weight and body fat may decrease in overtrained athletes (2,18,20). Body weight was constant while body fat decreased over the course of this study. It is difficult to conclude that decreased body fat with stable body weight is an adverse effect in subjects who compete in weight classes, as none had pathologically low levels of body fat. Loss of body fat may, however, be an early indicator of an overtraining response, as has been suggested (2,17,19).

It is possible that the physiological symptoms which an athlete develops are specific to the type of training or event. Thus, athletes performing predominantly anaerobic activities might exhibit different symptoms from those in endurance events. It has been suggested that explosive, non-endurance-type athletes such as judo players develop sympathetic-type symptoms (e.g., increased resting heart rate and blood pressure and weight loss) while endurance athletes develop parasympathetic symptoms (e.g., low resting heart rate, poor performance, and rapid recovery of heart rate after exercise) (17), but recent studies of overtrained endurance athletes have observed sympathetic-type symptoms (1,2,7,22). Neither of these symptom profiles was evident among the subjects in this study. So few recent studies have examined anaerobic sports, however, that it is still possible than athletes performing predominantly anaerobic activities develop symptoms other than those characterized to date.

Individual variability in the incidence of a specific symptom has also been observed (1,2,17,20,22). In this study, however, no individual athlete exhibited even a partial profile of symptoms consistent with the overtraining syndrome as currently described. In addition, the coach was unable to subjectively determine a subgroup of athletes in particular distress.

Costill et al. (4) and Kirwan et al. (16) recently completed a study of swimmers who suddenly doubled training volume. Their model of overtraining was similar to, though of shorter duration (10 d) than, the model used in this study, but they did not find that performance was adversely affected. This may reflect differences in the duration of the overtraining phases, 10 d compared to 6 wk.

When considered together, the overtraining performed in these studies had little adverse effect on the physiological well-being of the athletes. In contrast, very short-term overtraining may not affect performance (4,16), while a more prolonged period of overtraining may impair it. Performance may be affected before physical symptoms appear. Thus, monitoring athletes for the symptoms examined in this study is probably ineffective for detecting early overtraining effects. The selection of specific performance variables for monitoring also appears to be important as some may be more susceptible to overtraining than others. In this study strength was most affected although this may have been due to the large quantity of anaerobic training. Other aspects of performance may be more susceptible in other training programs. It is also important that these variables be closely related to the athlete's competitive event. In this study, although isokinetically determined strength and 300 m interval performance declined, other performance measures were not impaired. Therefore, we cannot be certain that judo performance was adversely affected.

Neither the incidence of overtraining nor the syndrome is precisely known. There is a widespread perception that overtraining is increasingly common and, perhaps, even necessary for success (2,19). It has also been suggested that the syndrome is rare (5). These somewhat different views are not necessarily incompatible. To date there has been a tendency to tolerate or even encourage overtraining (19) as long as the syndrome stage is prevented. The results of this study suggest that "overtraining" itself may have detrimental effects on performance without the development of the other symptoms of staleness. At the very least, an awareness of this possibility needs to be acknowledged when considering deliberate overtraining strategies.

Unfortunately, responses to overtraining such as those observed in this study may be widespread precisely because there are no obvious symptoms to alert the athlete. This may be particularly true in sports where performance is difficult to quantify, and it is possible that otherwise unexplained competitive losses or even unsuccessful seasons may be due to overtraining. This study had particular relevance for the athletes who participated. They routinely prepared for competition by increasing judo training to two sessions per day for the 2 wk immediately prior to competition (as simulated in phase III of this study) and did not taper as might be expected.

In this study, it appears justified to describe the training performed as overtraining, and some aspects of performance were adversely affected as a consequence. Thus, there is reason to be concerned that athletes may be limiting performance gains by training in this manner. Although manifestations of overtraining syndrome symptoms may alert athletes to overtraining consequences, failure to manifest symptoms should not be considered reassurance that overtraining is not detrimental to performance. Finally, elite athletes may be surprisingly capable of performing and even tolerating multiple forms of volume overload training of modest duration, yet most studies of overtraining have been surprisingly short. Therefore, the duration of overtraining may be an important factor that future studies attempting to investigate responses to overtraining need to consider.

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