

# Monitoring training in athletes with reference to overtraining syndrome

CARL FOSTER

Milwaukee Heart Institute, Milwaukee, WI

## ABSTRACT

FOSTER, C. Monitoring training in athletes with reference to overtraining syndrome. *Med. Sci. Sports Exerc.*, Vol. 30, No. 7, pp. 1164–1168, 1998. **Purpose:** Overtraining is primarily related to sustained high load training, often coupled with other stressors. Studies in animal models have suggested that unremittingly heavy training (monotonous training) may increase the likelihood of developing overtraining syndrome. The purpose of this study was to extend our preliminary observations by relating the incidence of illnesses and minor injuries to various indices of training. **Methods:** We report observations of the relationship of banal illnesses (a frequently cited marker of overtraining syndrome) to training load and training monotony in experienced athletes ( $N = 25$ ). Athletes recorded their training using a method that integrates the exercise session RPE and the duration of the training session. Illnesses were noted and correlated with indices of training load (rolling 6 wk average), monotony (daily mean/standard deviation), and strain (load \* monotony). **Results:** It was observed that a high percentage of illnesses could be accounted for when individual athletes exceeded individually identifiable training thresholds, mostly related to the strain of training. **Conclusions:** These results suggest that simple methods of monitoring the characteristics of training may allow the athlete to achieve the goals of training while minimizing undesired training outcomes. **Key Words:** QUANTITATING TRAINING, ATHLETIC PERFORMANCE, OVERTRAINING SYNDROME

Overtraining syndrome is a complex condition characterized by a variable group of symptoms and pathophysiologic abnormalities that always include performance incompetence refractory to normal regeneration cycles. Overtraining syndrome is frequently observed in response to sustained high intensity/high volume athletic training, particularly when coupled with other stressors in the individual's life (travel, occupation, inadequate sleep, etc.). Overtraining syndrome is a commonly occurring problem for at least two compelling reasons. First, the clear relationship between training load and performance encourages athletes to attempt to progressively heavier training loads in quest of the small (<2%) improvements in performance that define competitive results at the highest levels of competition (5,11). Second, the instinctive response of most athletes (as well as of athletic coaches) to unfavorable competitive or training results is to increase the effort of subsequent training sessions. In cases where fatigue resulting from overreaching is responsible for transient performance incompetence, reactive increases in training load are arguably the single most inappropriate response an athlete could make. Overtraining syndrome has been very difficult to study since there are virtually no adequate experimental models of the condition. As a result, our understanding of overtraining syndrome is based largely on uncontrolled ob-

servations in spontaneously occurring overtraining syndrome and extrapolations from experimental studies of overreaching (6,8). Further, and most critically, experimental evaluation of either appropriate or inappropriate responses to training has been difficult because until recently there has been no method for adequately quantitating the training load.

We have recently developed a simple modification of the rating of perceived exertion (RPE) scale originally developed by Borg (1) in which the participant is asked to rate the global intensity of the entire training session (4). When this intensity score is multiplied by the duration of the training session, a single number representing the magnitude of that training session is derived. The "session RPE" has been shown to relate to the average percent heart rate reserve during an exercise session and to the percentage of a training session during which the heart rate is in blood lactate derived heart rate training zones (4). With this method of monitoring training we have demonstrated the utility of evaluating experimental alterations in training (4) and have successfully related training load to performance (5). However, training load is clearly not the only training related variable contributing to the genesis of overtraining syndrome. The increased training volume and increased training intensity studies by Lehmann et al. (7) demonstrated rather different responses to substantially similar increases in training load. During the increased training volume study, the subjects developed performance incompetence as well as several other characteristics consistent with overtraining syndrome. During the increased training intensity study (with substantially more day-to-day variation in training

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load) the subjects demonstrated improved performances and few, if any, complaints consistent with overtraining syndrome. We (6,8) have reasoned that there must be other identifiable quantitative characteristics of the training program that might contribute to the genesis of overtraining syndrome.

Race horses often develop a syndrome that in many respects is similar to overtraining syndrome in human athletes. Bruin et al. (2) performed a long-term experimental study of progressively heavier training in a group of race horses. When training, conducted on a "hard day-easy day" basis, was incremented by increasing the magnitude of training on the "hard" day, the horses responded appropriately and improved their performance in response to the increased training load through several progressive increases in the training load. However, when the training load on the "easy" day was increased, the horses decompensated rapidly, developing symptoms consistent with the equine equivalent of overtraining syndrome. If one attempts to calculate the training loads of these horses using the reported heart rate and training durations, it is apparent that not only did the total training load increase with successive changes in training, but that the day-to-day variability of training decreased when the training load on the "easy" days increased. These observations suggested to us that some index of training variability might contribute, together with the total training load, to the genesis of overtraining syndrome.

In preliminary studies we have suggested that this index of training variability can be defined as the daily mean/standard deviation calculated over the period of a week (6). We have labeled this index "training monotony." Further, since high training load and high training monotony are both factors related to negative adaptations to training, we have suggested that the product of training load and training monotony, "training strain," may also relate to negative adaptations to training. Preliminary studies have suggested that the incidence of banal infections, which are often thought to be a marker of the early stages of overtraining syndrome (6,8), were related to excursions above individually identifiable thresholds of training strain. The purpose of this study was to extend our preliminary observations by relating the incidence of illnesses and minor injuries to various indices of training.

TABLE 1. Schematic evaluation of the load, monotony, and strain associated with a training program in an elite speed skater.

Day	Training Session	Duration (min)	RPE	Load
Sunday	Cycle (100 km)	180	5	900
Monday	Weight training	120	7	840
Tuesday	Cycle 10 km	20	2	40
Wednesday	Inline roller intervals	90	6	540
Thursday	Plyometrics	75	7	525
Friday	Cycle (10 km)	20	2	40
Saturday	Weight training	120	7	840
Daily Mean Load				532
Daily standard deviation of load				367
Monotony (Daily mean/standard deviation)				1.44
Weekly load (daily mean load * 7)				3725
Strain (Weekly load * Monotony)				5397

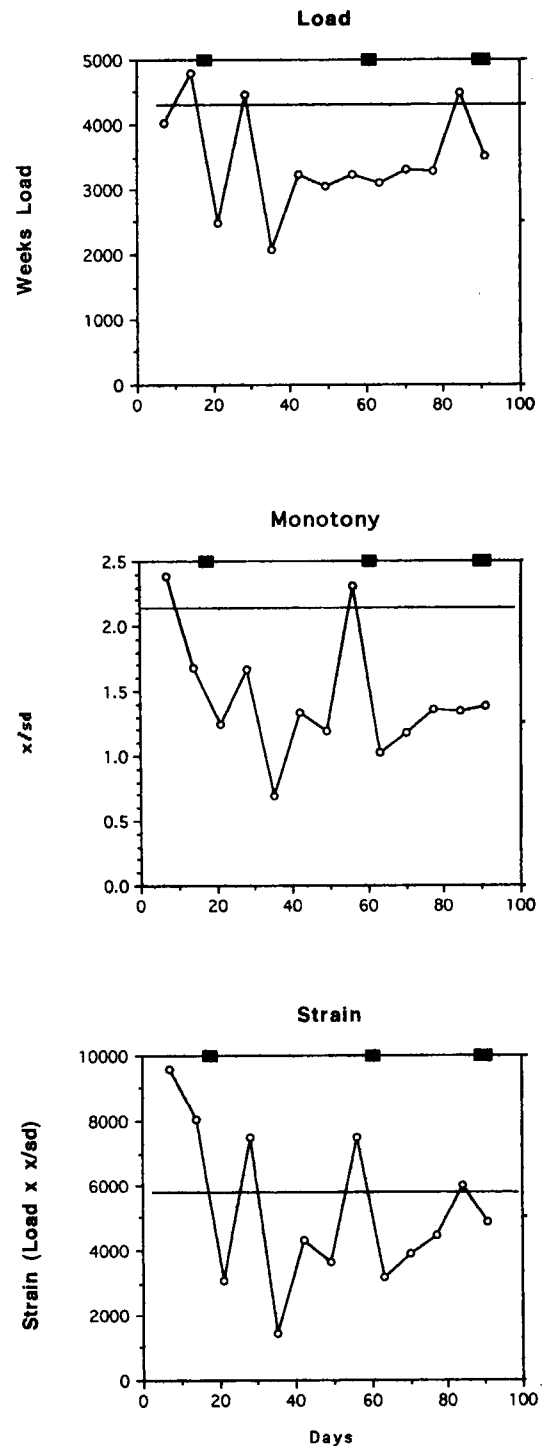


Figure 1—Schematic example of the strategy used to correlate episodes of illness with various indices of training. An individual "threshold" is identified (horizontal line) that explains most of the illnesses experienced by the athlete. In the top panel, two of the three episodes of illness are temporally related (within 10 d) to spikes of training load above ~4300 units per week, however one spike in training (~day 30) does not have a following illness, and one illness (~day 60) is not related to an increase in training load. In the middle panel, a similar relationship is noted for illnesses in relation to training monotony. Two of the three illnesses can be explained by spikes in training monotony, although one occurs at comparatively low levels of training monotony. In the bottom panel, the same relationship is plotted for training strain (weeks load  $\times$  monotony). All three illnesses can be explained by excursions above an individually identifiable threshold, although at least one increase in training strain above the threshold is not associated with illness (~day 30).

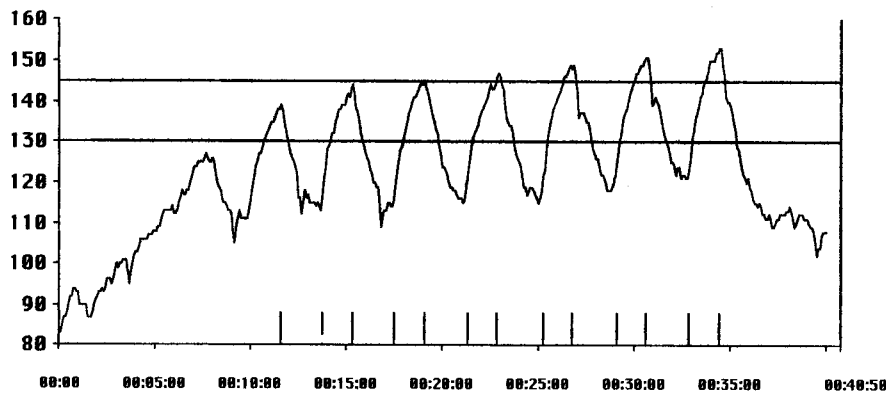


Figure 2—:Schematic example of the method used to calculate the global training score based on HR. The amount of time within various HR based zones is computed from the HR monitor, multiplied by the value of the zone, and summated to derive a  $\Sigma$  HR score. The HR zones are based on 50–60, 60–70, 70–80, 80–90, and 90–100% of the previously established  $HR_{max}$  for that mode of exercise in that athlete. The session RPE is multiplied by the duration of the exercise bout to derive a session RPE score.

## METHODS

The subjects for this study were serious competitive athletes (primarily speed skaters) ( $N = 25$  ( $M = 16$ ,  $F = 9$ )). Although their competitive level varied from low level competitors to members of U.S. National Teams ( $N = 8$ ) to members of U.S. Olympic Teams ( $N = 3$ ), all trained systematically and participated in a regular schedule of competitive events. On the average they were  $26.3 \pm 3.2$  yr of age. Their physical characteristics were substantially similar to those reported previously (11).

Each subject recorded his/her training over a period of time ranging from 6 months to 3 yr. Approximately 30 min following the conclusion of each training session, the subject was instructed to rate the global intensity of each training session using the category ratio scale developed by Borg (1) by answering a question such as might have been asked by a nontechnologically literate but interested observer of the training program, i.e., the athlete's mother, "How was your workout, honey?" This was intended to encourage the athlete to view the training session globally and to simplify the myriad of exercise intensity clues such as heart rate or blood lactate during training or the intensity of the terminal repetitions during the exercise bout. The duration of the entire training session (including warm-up, cooldown, and recovery intervals during the training session) was also noted. The product of the session RPE and session duration was termed the session "load." In the case where multiple training sessions were performed on a given day, the training load was summated for that day to create a daily training load. The training load during each week was summated to create a weekly training load. Additionally, the daily mean training load as well as standard deviation of training load were calculated during each week. The daily mean divided by standard deviation was calculated as "monotony." The product of the weekly training load and monotony was calculated as "strain" (Table 1). A simple plot of the number of weeks elapsed versus training load, monotony and strain was made (Fig. 1). The incidence of simple illness was noted and plotted together with the indices of training load, monotony, and strain. The correspondence between spikes in the indices of training and subsequent (within 10 d) illness was noted, and individual

thresholds that allowed for optimal explanation of illnesses were computed. From this we attempted to define the percentage of illness that could be explained by each index of training.

As an independent test of the ability of our "session RPE" method to track trends in training, seven subjects performed 50 training sessions, each wearing HR monitors. From these recorded sessions (Fig. 2), the duration in each training zone was calculated and multiplied by the value for that zone as suggested by Edwards (3). These scores were then summated to provide a single "score" for that training session based on heart rate criteria. This  $\Sigma$  HR score was then compared to the "score" created by the "session RPE" method.

## RESULTS

The session RPE method of quantitating the exercise training load was well related to the 229 HR time in zone method (Fig. 3). This further documents that our simple

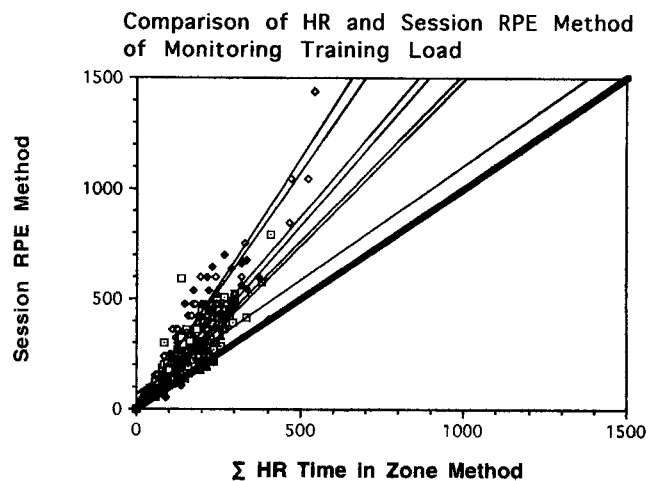


Figure 3—Comparison of the  $\Sigma$  HR score and the session RPE score for the same 50 exercise bouts in seven different subjects. The heavy line is the line of identity; the thinner lines are individual relationships. Note that although the two methods of quantitating exercise load are not numerically equivalent, they are fairly well related (individual correlations range from 0.75 to 0.90).

### Illness in Relation to Indices of Training

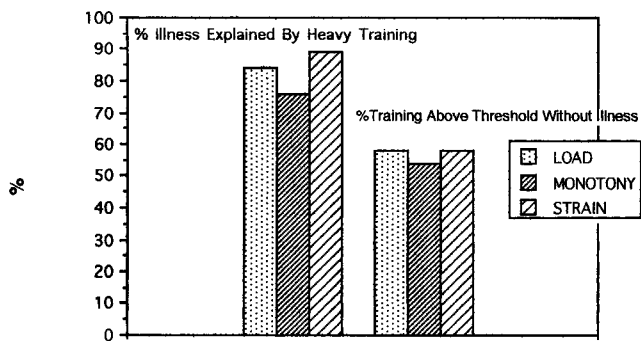


Figure 4—Percent of episodes of illness explained by the presence of a preceding (within 10 d) spike in training load, monotony or strain. Also depicted are the percent of spikes in training that occur without an associated illness.

extension of the use of the RPE concept provides a valid method of quantitating exercise training independent of technologically intensive methods of recording exercise training intensity.

With our approach of correlating the incidence of illnesses with indices of training, 84% of illnesses could be explained by a preceding spike in training load above the individual training threshold (Fig. 4). At the same time, not every excursion of training load above the individual threshold was associated with illness as 55% of the excursions above the threshold were accomplished without a temporally related illness. For training monotony, 77% of illnesses were associated with a preceding spike in training monotony; while 52% of the excursions of training monotony above the individually identified threshold were not associated with illness. For the product of training load and training monotony, training strain, 89% of illnesses could be explained by a preceding spike in training while 59% of the excursions of training strain above the individual strain threshold were not associated with illnesses.

## DISCUSSION

The presence of banal infections is not necessarily equivalent with the presence of overtraining syndrome. People get sick for a variety of reasons, often related to exposure to pathogenic bacterial or viral agents. At the same time, there is a well-known association between either chronic or acute heavy exertion and an increased incidence of infection (6,8,10). We feel that this may relate to a modest immunosuppression during periods of heavy training (or high levels of other stressors) that renders the individual more susceptible to infection by pathogens in the environment. This study is the first to demonstrate a quantitative relationship between various indices of training and the presence of negative adaptations to training. The results are reasonable in that an index such as training strain that integrates mul-

iple training stressors was more successful in explaining illnesses than individual stressors, and in an appropriate temporal sequence.

Previous studies, as well as extensive athletic experience, suggest that heavy training loads are ultimately necessary to achieve athletic success (5). The results of the present study, together with the animal model data of Bruin et al. (2), suggest that strategies designed to minimize training monotony (and thus training strain), primarily multiple "easy" days within each week may allow a given training load to be accomplished with comparatively fewer negative outcomes. As an example, at a training load of 4000 units per week (comparable with the load undertaken by many contemporary elite athletes) there is a large reduction in training strain when "hard" training days are only performed 4 d-wk (with 2 "easy" days and 1 "off" day) compared with slightly less severe "hard" days performed 6 d-wk (with 1 "off" day) (Fig. 5).

The concept that training factors other than load may contribute to the genesis of overtraining syndrome is most attractive since it offers the possibility that athletes may still train at very high loads if they can devise strategies for controlling the strain of training. The hypothesis that training monotony may be involved is very attractive in that it accounts for some of the negative adaptations to heavy training (banal illnesses), is consistent with animal model data (2), is consistent with the observations from increased training volume, increased training intensity, and intensive ergometer training studies which are the best experimental models of overtraining syndrome (7,9), and is consistent with nutrient, neuro-transmitter depletion, and sympathetic down regulation models of overtraining syndrome (cf 6,8).

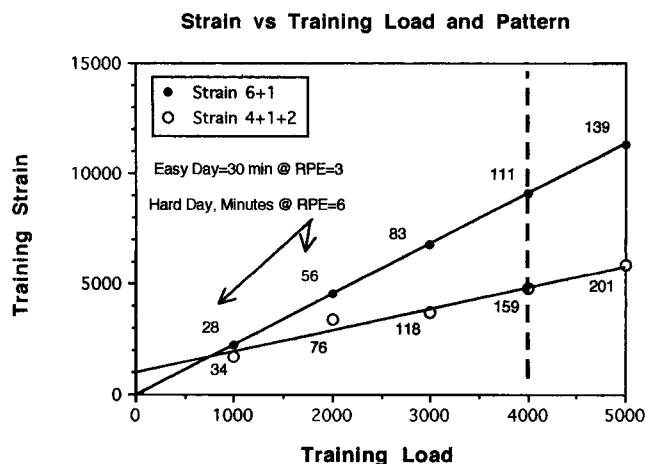


Figure 5—Schematic example of the changes in training strain resulting from changes in the pattern of training to include two recovery days (30 min @ RPE = 3) per week while maintaining the same total training load vs 6 d of more or less equivalent "hard" training. Note that although the required duration of training on "hard" days increases, the reduction in training monotony resulting from more variable training leads to a reduction in the calculated strain of the training program. At a training load of 4000 units per week (consistent with the training programs of many contemporary athletes) the duration of training on the "hard" days is still within reasonable limits, but the net strain related to training is reduced compared with training that is more similar on a day to day basis.

The present observations are suggestive of a strategy by which heavy training might be accomplished with a comparative reduction in the negative outcomes of training. They need to be confirmed with prospective experimental training studies similar in scope to the intensive ergometer

training study of Lehmann et al. (9) or the cross-training study from our laboratory (4).

Address for correspondence: Carl Foster, Ph.D., Milwaukee Heart Institute, Milwaukee, WI 53201-0342. E-mail: cfoster@facstaff.wisc.edu.

## REFERENCES

1. BORG, G., P. HASSMEN, and M. LANGERSTROM. Perceived exertion related to heart rate and blood lactate during arm and leg exercise. *Eur. J. Appl. Physiol.* 65:679-685, 1987.
2. BRUIN, G., H. KUIPERS, H. A. KEIZER, and G. J. VANDERUIJSSE. Adaptation and overtraining in horses subjected to increasing training loads. *J. Appl. Physiol.* 76:1908-1913, 1994.
3. EDWARDS, S. *The Heart Rate Monitor Book*. Sacramento, CA: Fleet Feet Press, 1990, pp. 113-129.
4. FOSTER, C., L. HECTOR, R. WELSH, M. SCHRAGER, M. GREEN, and A. C. SNYDER. Effects of specific versus cross training on running performance. *Eur. J. Appl. Physiol.* 70:367-372, 1995.
5. FOSTER, C., E. DAINES, L. HECTOR, A. C. SNYDER, and R. WELSH. Athletic performance in relation to training load. *Wisc. Med. J.* 95:370-374, 1996.
6. FOSTER, C. and M. LEHMANN. Overtraining syndrome. In: *Running Injuries*, G. N. Guten (Ed.). Philadelphia: W.B. Saunders, 1997, pp. 173-188.
7. LEHMANN, M., P. BAUMGARTL, C. WIESENACK, et al. Training-overtraining: Influence of a defined increase in training volume vs training intensity on performance, catecholamines and some metabolic parameters in experienced middle and long distance runners. *Eur. J. Appl. Physiol.* 64:169-177, 1992.
8. LEHMANN, M., C. FOSTER, and J. KEUL. Overtraining in endurance athletes: a brief review. *Med. Sci. Sports Exerc.* 25:854-862, 1993.
9. LEHMANN, M., K. KNIZIA, U. GASTMANN, et al. Influence of a 6 week, 6 days per week training on pituitary function in recreational athletes. *Br. J. Sports Med.* 27:186-192, 1993.
10. PETERS, E. M., B. GOETZSCHE, B. GROBBELAAR, and T. D. NOAKES. Vitamin C supplementation reduced the incidence of postrace symptoms of upper respiratory tract infection in ultramarathon runners. *Am. J. Clin. Nutr.* 57:170-174, 1993.
11. SNYDER, A. C. and C. FOSTER. Physiology and nutrition for skating. In: *Perspectives in Exercise Science and Sports Medicine, Vol. 7: Physiology and Nutrition of Competitive Sports*, D. R. Lamb and H. G. Knuttgen (Eds.). Indianapolis: Cooper Publishing Group, 1994, pp.181-219.