

ABSTRACT

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The structure of training programs is of interest for athletes desiring peak performance. Ideally, the athletes' experiences should be equivalent to the coaches' intentions. Based on previous studies it was hypothesized that athletes would not execute the program designed by coaches. Members of the U.S. Speedskating team ($n = 11$) completed a daily training log during the course of a training/competitive season (7 months) in which athletes and coaches recorded their intensity (session Rating of Perceived Exertion) and duration (time) of training. Although there was a good correlation for training duration ($r = 0.60$), intensity ($r = 0.63$) and calculated load (intensity * duration) ($r = 0.59$), comparisons of the mean values for duration, intensity and load for sessions the coach intended to be easy, moderate and hard revealed significant differences. Athletes were training harder on coach-intended easy days (load = 106 vs. 8 units), about as intended on coach-intended moderate days (load = 424 vs. 416 units) and easier on coach-intended hard days (load = 883 vs. 970 units). These data suggest that athletes are not taking recovery days as intended by coaches. These findings may provide an explanation for some undesired training outcomes and for the high incidence of overtraining syndrome in elite athletes.

**MONITORING TRAINING IN ELITE ATHLETES:
COMPARISON OF COACHES' INTENTIONS
AND ATHLETES' EXPERIENCES**

**A MANUSCRIPT STYLE THESIS PRESENTED
TO
THE GRADUATE FACULTY
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OF THE REQUIREMENTS FOR THE
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**BY
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THESIS FINAL ORAL DEFENSE FORM

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We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

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The candidate has successfully completed the thesis final oral defense.

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INTRODUCTION

Training enhances the capacity of an athlete to meet the requirements for success in a particular sport. The structure of a training program is of critical interest to the coaches of elite athletes. These athletes need to be at their peak performance during certain times of the season. Coaches try to optimize the performance of athletes when designing a training program. However, since the athletes' focus is primarily of training, the relationship between the coach and athlete will determine subsequent improvements in athletic performance, and it is necessary for the coach to design an appropriate training program. It is also important for the athlete to execute the coach's plan.

Athletes attempt to improve upon their own performances as well as strive for world record performances. Coaches and athletes experiment with several styles of training to come up with the correct training load that optimizes the training response. The training load is quantitatively assessed by the integration of overall intensity and duration, thereby generating a single training input number (1,8). This concept has evolved to provide the athlete and coach with a better understanding of the imposed load placed on the athlete.

Coaches try to implement successive fatiguing work-relief cycles in order to maximize athletic performance (11). They are using the evolution of the fitness and fatigue responses of training as identified by Fitz-Clarke, Morton and Banister (3,16) to increase their performance levels. The interaction between the antagonistic

components of fitness and fatigue affects the performance of the athlete. The Fitness-Fatigue model indicates the momentary performance readiness of an athlete (8). The critical point at which further increments in fatigue are greater than that of fitness is where the reduction in training should begin. The goal of tapering before competition is to maintain the physiologic adaptations achieved during intensive training while the negative (fatigue) impact of training resolves (17). The determination of the time needed to achieve optimal performance and the period of reduced training before competition where the level of fitness outweighs fatigue is of importance to the competitive athletes. They can optimize their performance if the time period of reduced training to peak performance is known (3).

The factor of motivation drives these athletes to push themselves, occasionally beyond their adaptive limits. As athletes are completing the coach-designed training program, they are pressured to ignore the day-to-day fatigue and possibly overreach the intended training effect (10). In a recent study in our laboratory, athletes were observed to be completing harder training on days the coach scheduled as easy, and not working hard enough on days the coach scheduled as hard (9). This emphasizes the necessity of monitoring the interplay between coaches and athletes (6,18).

It has been documented that there was approximately a 10% improvement in performance for a 10-fold increase in training load (5). When an athlete's performance decreases, both the coach and athlete tend to increase the training load to elicit a desired outcome. If this concept is magnified and further sustained for a long period of time with inadequate recovery periods, a negative outcome may occur, perhaps leading to

overtraining syndrome (OTS) (13,14). This takes place when excessive stress is combined with inadequate time for regeneration (4,15,20).

In order to prevent OTS, monitoring of the coaches' intended and athletes' actual training programs is needed to ensure that adequate recovery time is given and indeed taken (19). By keeping a training log, which records variables such as overall intensity and duration, a training load can be quantified. Establishing the training load that optimizes the athletes' performance potential while allowing for a balance between training and recovery is the key to success (12). Determining whether the athlete is following the intended training plan is a way to better understand the stress placed on the athlete and to explain whether any deviation from the plan is related to deterioration in performance.

An undesired training outcome may be caused by the athletes not properly executing the training plan designed by their coaches (6). This hypothesis has been experimentally supported, but only with sub-elite athletes over a short time period (9). There were interesting and provocative findings which suggest the need to extend the study by testing elite athletes over a comparatively longer period of time.

This study will test the hypothesis that elite athletes do not execute the training plan as designed by their coaches. If this hypothesis is supported, an important step toward the understanding of how a training program contributes to athletic success or to an undesired training outcome will be explained.

METHODS

Members of the elite all around and sprint training groups of the U.S. Speedskating team were subjects for this study (n=11). Physical and demographic characteristics are presented in Table 1. Seven males and four females participated in this study. These athletes trained in Park City/Salt Lake City, UT and in Milwaukee, WI. This study was approved by the Institutional Review Board for the Protection of Human Subjects of the University of Wisconsin-La Crosse. Prior to any testing all subjects signed an informed consent form. Former Olympic team members constituted half of the team including Olympic and World Championship medallists as well as current and former world record holders. The rest of the sample included members of the U.S. Junior National Team.

Table 1. Subject Characteristics (mean \pm standard deviation)

Variable	Male (n=7)	Female (n=4)
Age (years)	24 \pm 3	24 \pm 1
Height (cm)	179 \pm 9	166 \pm 3
Weight (kg)	74 \pm 5	61 \pm 2
% Body Fat	6 \pm 2	16 \pm 1
VO ₂ max	65 \pm 7	60 \pm 3

A well-validated system of monitoring training programs designed for the elite speedskating team was used. They were followed throughout their training programs during a seven-month period of both dry land and on-ice training. Daily training log-questionnaires were completed in order to obtain the data necessary to determine whether the coaches' training programs were congruent with the execution of the athletes. These contained a series of items that were needed to calculate training load and lead to the determination of whether undesired training outcomes were associated with the design and execution of the programs.

The widely used session RPE method was used to assess the global intensity of training. With the use of the Rating of Perceived Exertion (RPE) scale (0-10) we obtained the overall intensity of the workout (1,2). The athlete recorded this rating approximately 30 minutes following each training session along with the duration of the workout. Each coach rated their intentions for the overall intensity (session RPE) and duration separate from the athletes. They were also asked to briefly describe the type of training completed for each day. Any illness or injury that was either new or ongoing was described. A Complaint Index assessed the level of muscular aches and pains in the evening and the state of mental well being was assessed using a 1-5 Lickert Scale. The overall intensity recorded as the session RPE was multiplied by the duration of the session to determine the training load (7). Identification of deviations from the training plan were noted when the load was summated over a weekly time period and a pattern of the training loads was displayed.

The analysis of this data was developed by Foster and colleagues (9), which represented an adaptation to an Excel spreadsheet. Figures for daily and weekly training loads were produced to analyze the training structure. Regression statistics were used to compare the coaches' intentions and the athletes' experiences for the training sessions. A two-way ANOVA with repeated measures was used to evaluate the training load, intensity, and duration for training sessions designed to have low (RPE < 3), intermediate (RPE 3-5), and high (RPE > 5) intensity. These were computed and analyzed for relationships between the coaches' intentions and athletes' experiences in regards to training and undesired training outcomes.

RESULTS

The serial variations between the athletes' and coaches' perceptions of training were correlated among Time, RPE, and Load to determine whether the elite athletes were executing the coach-designed training program (Figures 1-3). The data revealed that the athletes tended to train at an increased training load relative to the lighter workouts scheduled by the coaches. Consequently, at higher training loads the athletes did not, or possibly were not able, to train at the training load intended by the coaches. The Time and RPE data followed the same pattern, indicative of the fact that the athletes are not properly executing the coach designed training program. When the athletes' and coaches' data were compared, a good correlation existed for training duration (Time) ($r=0.60$), overall training intensity (RPE) ($r=0.63$), and training Load (RPE x Time) ($r=0.59$) (Tables 2-4).

A two-way ANOVA with repeated measures was used to compare the training sessions the coach intended to be easy (RPE < 3), moderate (RPE = 3-5), and hard (RPE > 5) to those of the athletes (Figures 4-6). It was found that there were significant differences between the coaches' intentions and the athletes' experiences within each intended workout. For sessions intended by the coaches to be relatively easy, the variables of Time, overall training intensity (RPE), and Load experienced by the athletes were all significantly greater than intended by the coaches, using the mean \pm standard deviation (4.2 ± 14.9 vs 23.5 ± 50.3 , $.1\pm .5$ vs 1.0 ± 2.0 , and 7.9 ± 28.1 vs 105.8 ± 323.8 ,

respectively). For sessions intended by the coaches to be of moderate intensity, there was only a significant difference for Time as intended by the coaches and not executed by the athletes (109.6 ± 37.1 vs 96.0 ± 63.0). There were no significant differences between the overall training RPE ($3.7 \pm .7$ vs 3.4 ± 2.3) or training Load (416.2 ± 196.6 vs 424.7 ± 395.2) experienced. For sessions intended by the coaches to be of hard intensity, the overall training RPE (7.4 ± 1.2 vs 5.9 ± 2.7) and training Load (970.1 ± 417.1 vs 883.0 ± 578.4) were significantly less than intended by the coaches, although there were no significant differences in training Time (130.9 ± 50.8 vs 132.0 ± 71.7).

Table 2. Comparison of Time Between Coaches' Intentions and Athletes' Experiences During Easy, Moderate, and Hard Training Sessions (mean \pm standard deviation)

Training Session	Coach	Athlete
Easy	$4.2 \pm 14.9^*$	23.5 ± 50.3
Moderate	$109.6 \pm 37.1^*$	96.0 ± 63.0
Hard	130.9 ± 50.8	132.0 ± 71.7

*Indicates significant difference ($p < .05$).

Table 3. Comparison of RPE Between Coaches' Intentions and Athletes' Experiences During Easy, Moderate, and Hard Training Sessions (mean \pm standard deviation)

Training Session	Coach	Athlete
Easy	$.1 \pm .5^*$	1.0 ± 2.0
Moderate	$3.7 \pm .7$	3.4 ± 2.3
Hard	$7.4 \pm 1.2^*$	5.9 ± 2.7

*Indicates significant difference ($p < .05$).

Table 4. Comparison of Load Between Coaches' Intentions and Athletes' Experiences During Easy, Moderate, and Hard Training Sessions (mean \pm standard deviation)

Training Session	Coach	Athlete
Easy	7.9 \pm 28.1*	105.8 \pm 323.8
Moderate	416.2 \pm 196.6	424.7 \pm 395.2
Hard	970.1 \pm 417.1*	883.0 \pm 578.4

***Indicates significant difference ($p < .05$).**

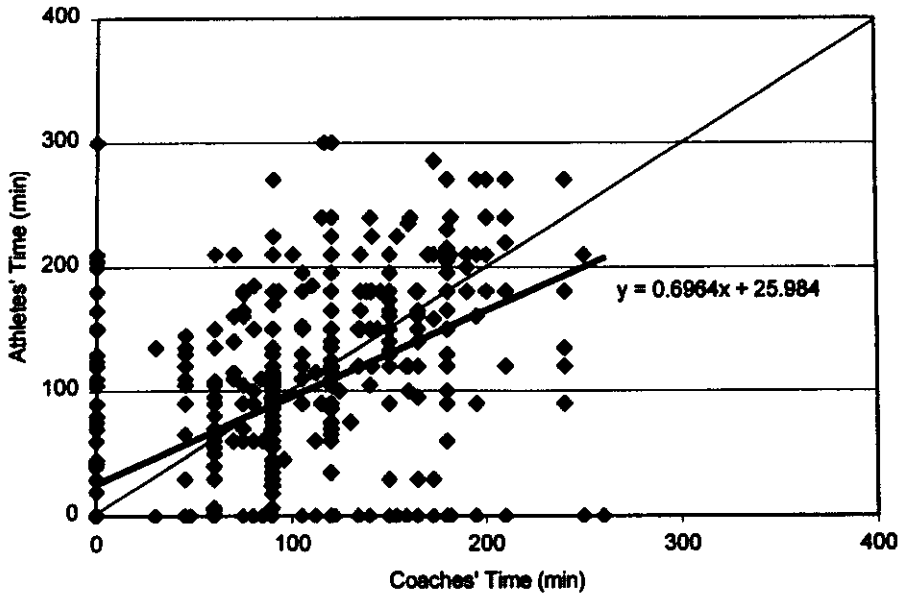


Figure 1. Correlation of Time Between Coaches' Intentions and Athletes' Experiences

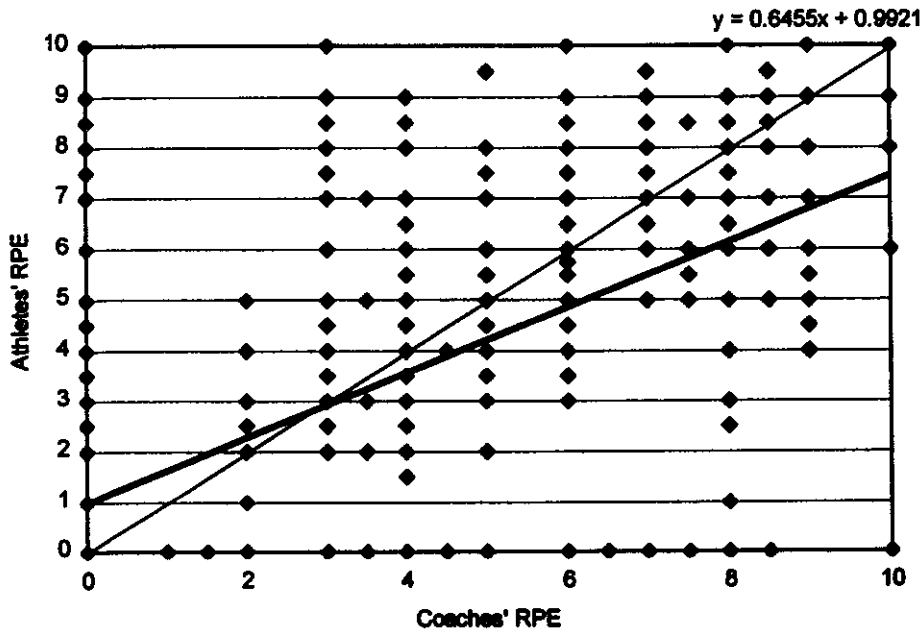


Figure 2. Correlation of RPE Between Coaches' Intentions and Athletes' Experiences

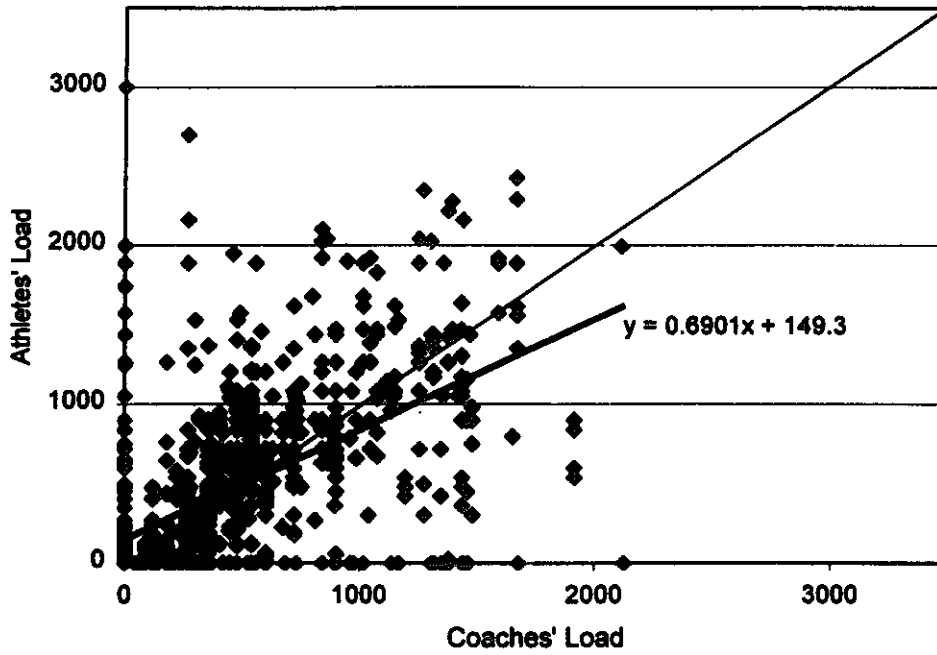


Figure 3. Correlation of Load Between Coaches' Intentions and Athletes' Experiences

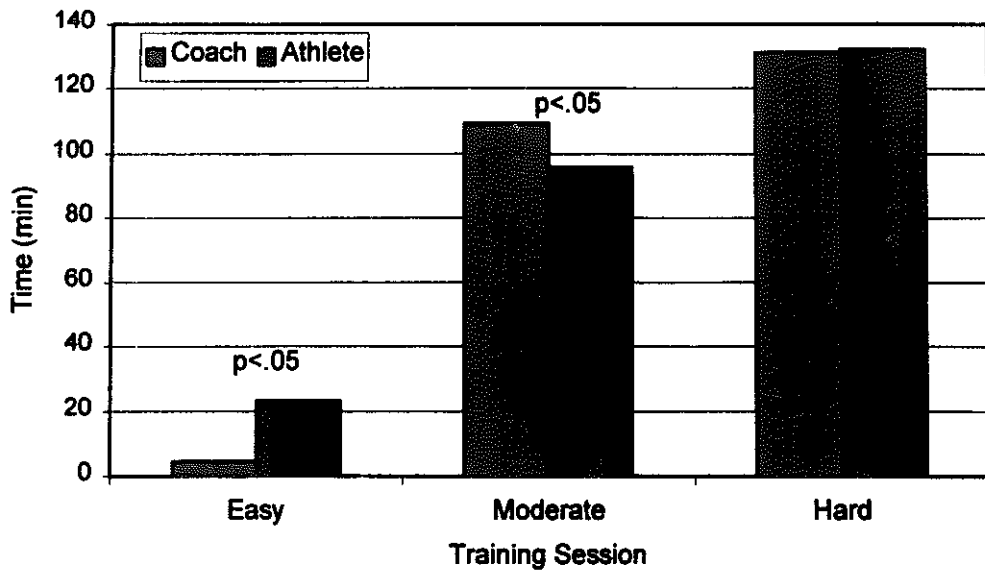


Figure 4. Comparison of Time Between Coaches' Intentions and Athletes' Experiences During Easy, Moderate, and Hard Training Sessions

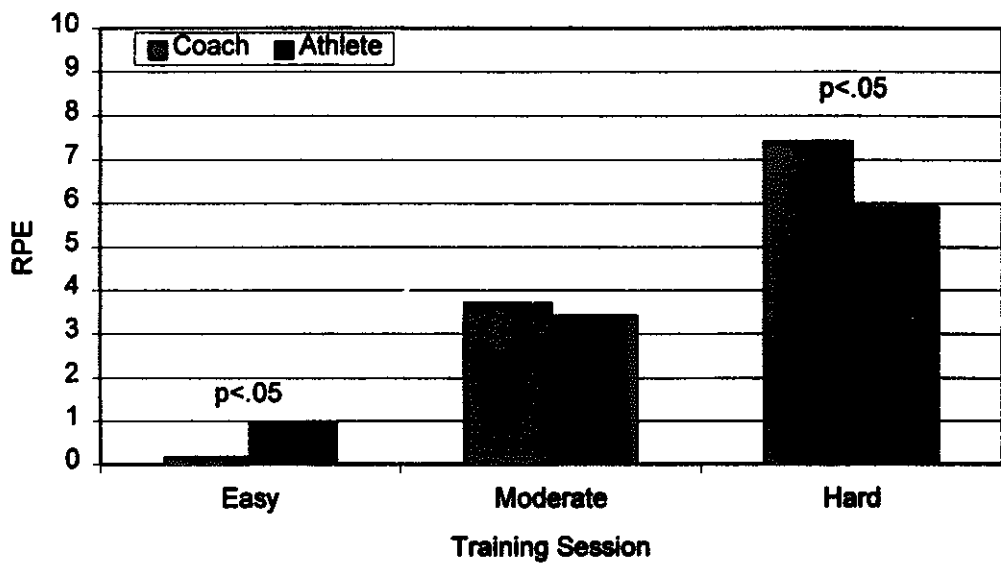


Figure 5. Comparison of RPE Between Coaches' Intentions and Athletes' Experiences During Easy, Moderate, and Hard Training Sessions

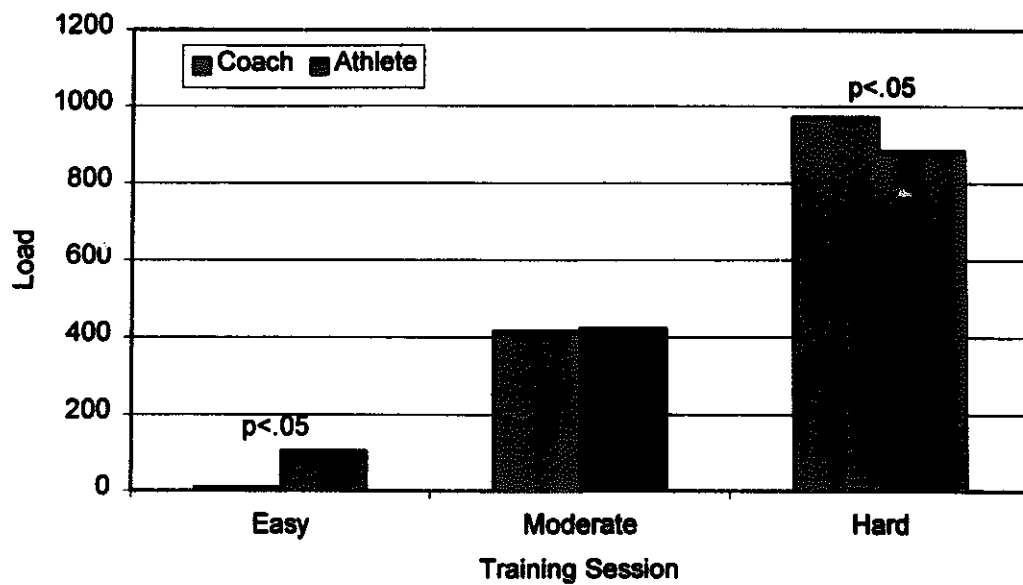


Figure 6. Comparison of Load Between Coaches' Intentions and Athletes' Experiences During Easy, Moderate, and Hard Training Sessions

DISCUSSION

There was a statistically significant and athletically meaningful disparity between the coaches' intentions and the athletes' experiences in training. The results of this study confirm that athletes train harder on coach-intended easy days and easier on coach-intended hard days. Athletes experiment with several styles of training to determine the training response that will best improve their performance. Eventually the correct training load is established and a periodized plan is implemented. When an athlete deviates from this plan, various undesired responses may be observed. When excessive stress is coupled with inadequate recovery time, overtraining syndrome (OTS) may develop and cause negative outcomes in performance (4,15). As seen in the elite athletes, when they work too hard on the relatively easy days they are not able to complete the appropriate training load on the harder scheduled sessions. Although no definable OTS was seen in the study, many of the elite athletes reported various muscle aches and pains along with a lower state of mental well being.

This study supports the previous findings obtained in sub-elite athletes over a shorter period of time (9). This study collected data throughout a six-month time period which should lead to a more reliable conclusion. The quantification of the training load was replicated within this study and the results exemplified the finding that athletes are not following the coaches' intended training plan. This has been recognized as a common training error in which athletes train too hard on the easy days and too easy on

the hard days (6). This knowledge of training and quantification of a training load creates a better understanding of the stress and recovery placed on the athlete. It further justifies that any deviation from the plan can be related to deterioration in performance.

Currently there is no research that disagrees with the previous findings (9) or with the results of the current study. Continued research is necessary to determine the efficacy of the training programs designed by the professionally trained coaches. Every athlete is unique in his/her own way and deserves an individualized training program.

It should be noted that this study is an observational design versus an experimental design. The coaches' intentions were assumed to have the correct training load for each athlete and deviations from that plan were assumed to be of practical importance. There were instances when the data were not being returned in a timely manner. In order to obtain the necessary data many options were made possible. One option was an e-mail design, which progressed to a written journal. These were either sent back through the mail or relayed by the phone. Many of these elite athletes were required to be on the road for a substantial period of time for training and competition. The recall of their training during these periods was not as accurate as it was when rated within approximately 30 minutes following each training session. The rating of perceived exertion (RPE) is a subjective method versus an objective method for the monitoring of training. The method of using a subjective session RPE to obtain an overall training intensity has been validated as a new approach to monitoring exercise training. (8) The session RPE method is a reliable tool in the quantification of training load for a wide variety of training sessions.

This study used a validated method to suggest that athletes are not properly executing their coaches' intended training plan. A better understanding of whether the athletes are given adequate recovery time and whether it is indeed taken will be of importance in determining the development of a negative performance outcome or OTS. Incorporating a method of monitoring training for coaches and athletes will provide a way to quantify training load. Establishing the training load that optimizes the athletes' performance potential, while allowing for a balance between training and recovery, is the key to success.

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APPENDIX A
INFORMED CONSENT FORM

Informed Consent Form:

**Monitoring Training in Elite Athletes:
Comparison of Coaches' Intentions and Athletes' Experiences**

I, _____ give my informed consent to participate in this study designed to monitor the training of athletes. This study is being conducted to acquire information pertaining to the training programs experienced by athletes and how well this matches to the training program designed by the coach. I consent to the publication or presentation of results as long as identity is not released.

I have been informed that the only risks associated with this study are within the scope of training including fatigue, muscle soreness and injuries. There are no foreseeable risks involved with the recording of training data.

I have been informed that by completing the training log-questionnaire I will be provided with information that could eliminate some common mistakes in training and this information will allow my coach to design a better training program for me.

I have been informed that I will be required to complete a daily training log-questionnaire, which could take 10 minutes to fill out. The training log-questionnaire involves reporting on intensity and duration, along with questions regarding illness, injury, muscular aches and pains, and state of mental well-being. Data collection will begin July 2000 and continue through January 2001.

I have been informed that the training logs will be in the investigator's possession at all times. Discussion may occur between the investigator and the research advisor in order to configure the data for adequate completion of the project.

I have been informed that any questions regarding the procedures in this study can be addressed to Shana VanWychen, Graduate Student in the department of Exercise and Sport Science, UW-La Crosse or Dr. Carl Foster, Faculty Research Advisor in the ESS department at UW-La Crosse. Questions regarding the protection of human subjects may be addressed to Dan Duquette, Chair, UW-La Crosse Institutional Review Board (608) 785-8155.

I have been informed that my participation is voluntary and I may withdraw from this study at any time without penalty.

Participant's Signature: _____ Date: _____

Parental Signature: _____ Date: _____
(If less than 18 years of age)

Investigator: _____ Date: _____

APPENDIX B
TRAINING LOGS

U.S. Speedskating Training Log

Please complete the following training log. Don't report how you think you should have felt for the workout but report how things actually felt.

Describe briefly your training today (e.g., roller intervals in AM, endurance weights in PM).

How long did the morning workout take in minutes? How much was warm-up, cool-down, standing around, and how much was actual workout?

Using the attached Rating of Perceived Exertion Scale, rate the overall difficulty of the workout as you would describe it to a friend, who after you had finished your shower asked, "How was your workout?" If it was a killer, it will be 8-10. Even if the momentary intensity never got very high (e.g., long cycle workout), the workout may still feel fairly hard because of the duration. In other words, rate the perceived effort.

How long did the afternoon workout take in minutes? How much was warm-up, cool-down, standing around, and how much was actual workout?

Using the attached Rating of Perceived Exertion Scale, rate the overall difficulty of the workout as you would describe it to a friend, who after you had finished your shower asked, "How was your workout?" If it was a killer, it will be 8-10. Even if the momentary intensity never got very high (e.g., long cycle workout), the workout may still feel fairly hard because of the duration. In other words, rate the perceived effort.

Did you do any other exercise today that wasn't directly related to training (e.g., walking 30 minutes to the store)?

Describe it.

How long did it take (minutes)?

What was the perceived effort?

Are you ill? Describe.

Are you injured? Is this new, or something ongoing? Describe.

Describe the level of muscular aches and pains in the evening (e.g., Complaint Index).

1=Muscles feel great

2=Muscles Tired, but no specific complaints

3=Noticeably achy, twitchy

4=Very achy, twitchy

5=Do I have to get out of bed?

What is your state of mental well being (happy, focused, clear minded, etc)?

1=I feel great, goals are attainable, bring on the Dutch

2=I think I can, I think I can, I think I can

3=OK, I'm here, don't expect a celebration

4=I've had better days, where coach and everyone else would leave me alone

5=Why am I wasting my time with this stuff?

Perceived Exertion Scale

0=Rest

1=Very Easy

2=Easy

3=Moderate

4=Sort of Hard

5=Hard

6=Hard!

7=Very Hard

8=Bad Words

9=Very Bad Words

10=Maximal

APPENDIX C
REVIEW OF RELATED LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

The fundamental act of training leads to the development of one's athletic performance level. Improving this performance level demands maximal concentration and motivation of the athlete. An athlete strives for competitive success during a training period and needs to be at peak performance during certain times of the season. Improving the athletic performance level of an athlete is what the coach tries to optimize when designing a training program. An athlete's focus is primarily on training, therefore the relationship between the coach and the athlete will determine subsequent improvements in athletic performance.

Certain training techniques have resulted from many trial-and-error observations of professional coaches, all stemming from concepts such as the general adaptation syndrome, overload principle, and periodization. These concepts relate to the training aspect of developing sufficient levels of fatigue along with proper recovery periods to elicit an improved physical (fitness) capacity for optimizing levels of performance. A method of monitoring training is essential to determine whether athletic performance has improved throughout the different training interventions of an athlete. Performance generally improves with training, therefore the relationship between athletic performance and training load needs to be quantitatively expressed. To understand this training response, a method to represent the training load for a given training session has been

developed. As early as 1968, Cooper (10) developed the "aerobics" point system as a preventative medicine practice for the American people. Fitz-Clarke, Morton and Banister (22,32) developed the training impulse (TRIMPS) concept using the average percent of heart rate reserve during training along with the training session duration. Foster and Colleagues (18) later expanded this method of monitoring training by using the category ratio version of Borg's Rating of Perceived Exertion scale (4,5). This provides the athlete and coach with a better understanding of the imposed load placed on the athlete.

The following provides a review of literature pertaining to: (1) the general concepts in the approaches to monitoring training, (2) the relationship of athletic performance to training load, (3) training characteristics in the development and adaptation of training, and (4) support for a contemporary approach to the monitoring of training.

General Concepts in the Approaches to Monitoring Training

Aerobics Points System. The development of the "aerobics" points system in 1968 allowed the American people to exercise safely and to effectively monitor their training program (10). The point system was based on the amount of oxygen utilized for the intensity and duration of physical activity. The increase in energy requirements (oxygen consumption) expressed in ml/kg/min helped to define the point system and establish the goal for fitness-based programs. Cooper found that the energy cost for walking one mile between 19:59 and 14:30 minutes related to an average of 7 ml/kg/min and awarded 1 point for this activity. To assure a better training response you must work

at a higher level. The foundation of 1 point for every 7 ml/kg/min allowed people to quantitatively monitor training by integrating the use of intensity and duration. Combining the intensity and duration to produce a single number representing the training input that could enhance performance was an effective tool. However, this approach is limited by its use of the absolute exercise intensity instead of the relative exercise intensity. The relative exercise intensity produces a greater training stimulus for the athlete in training (12).

Training Impulse Concept. A systems model to quantify and optimize training was developed by Fitz-Clarke, Morton, and Banister (22,32) along with Banister, Clavert, and Bach (2). This was a two-component systems model of monitoring the effects of training with a basic assumption that performance (output function) is related to the training load (input function). The interaction between the antagonistic components of fitness and fatigue affects the performance of the athlete. A training impulse (TRIMPS) concept was introduced in this model. This is a quantitative assessment that takes into account the duration of exercise and the intensity of the heart rate response (average percent of heart rate reserve) for each training session and creates a training impulse score in units of training. This method generates a single training input number to allow for the determination of the training load imposed on the athlete.

This dimensionless score provides an evaluation of the positive and negative effects that daily training produces from the beginning of a training program to the point of competition. Each training session has an influence on performance. This presents a form of monitoring the time frame prior to the critical period before competition. The

critical point at which further increments in fatigue are greater than that of fitness is where the reduction of training should begin. The further manipulations of the fitness (positive) and fatigue (negative) functions help athletes to achieve their potential. The determination of the time needed to achieve optimal performance and the period of reduced training before competition where the level of fitness outweighs fatigue is of importance to the competitive athlete. Athletes can optimize performance if the time period of cessation of training to peak performance is known (22).

A second method was created by Mujika and colleagues (34) and further assessed by Busso and colleagues (8,9) that takes into account the time-varying responses to training. This expanded the previous model by incorporating multiple components of training into the quantified training load. The time-invariant model could not account for a prolonged period of training with repeated periods of intensive and reduced training (8). The adaptations to training and long-term fatigue are better represented with time-varying parameters (gain terms and time constants). Therefore, the time-varying model is more suitable to assess the responses to training with a program having day-to-day variations (9).

Rating of Perceived Exertion Method. The session RPE method quantifies the training load in order to evaluate an athlete's training regimen. The TRIMPS concept integrated the average percent of heart rate reserve for training intensity, which is dependent on collecting heart rate recordings. Monitoring heart rates has progressed by the use of contemporary heart rate monitors worn during training sessions. Whether the heart rate monitor is worn or if there is a technical malfunction determines the extent of

daily training intensity accuracy. Heart rate monitors also fail to represent very high intensity exercise (e.g., repetition training/time trials) and exercise effort during resistance training. When training in a group, heart rate monitors do not reflect an accurate measurement due to the space needed for the recording mechanism to function.

In order to replace the heart rate measurement, Foster and colleagues (18) developed a method of monitoring training based on using the category ratio version of Borg's Rating of Perceived Exertion scale (4,5) as the index of training intensity. Athletes must consider the overall effort put forth in their training session to determine their RPE score. This global estimate of training intensity is recorded approximately 30 minutes after the conclusion of a training session. A single number representing "input" of the session, the training load, is calculated by multiplying the RPE by the duration of the session (in minutes). This training load is further used to assess exercise training over the duration of a week, day-to-day variability termed monotony, and the strain of training. By plotting the variables load, monotony, and strain over time, the pattern of training imposed on the athlete can be evaluated.

Foster, Florhaug, and Hrovatin (19) have assessed fitness and fatigue parameters using the training load variable. The time period of six to eight weeks represents the fitness of an athlete. The fatigue resulting from training refers to the training load during the last week. Therefore, the performance readiness of an athlete is calculated as fitness minus fatigue.

The session RPE method of quantifying the exercise-training load has been validated through training studies. A good relationship between the training "session"

RPE and heart rate behavior in relation to the common blood lactate transition zones was noted (18). This training load also related well to the heart rate time zone method (summated heart rate score) (13). The session RPE method is not dependent on obtaining heart rate data and it can be used for very high intensity training. This method of monitoring training allows the athlete and coach to have some objective evaluation of a training regimen.

Relationship of Athletic Performance to Training Load

Athletes attempt to improve upon their own performances as well as strive for world record performances. To reach a specific performance level, an athlete and coach experiment with several styles of training to come up with the correct training load that elicits the desired response. In order to evaluate an athlete's training regimen, both performance and physiological criteria are needed. Foster and Daniels (15) have developed a conceptual model of performance. Determinants in this model include physiological, training, experiential and environmental factors. Frequency, intensity, and duration of training are important training indices relating to athletic performance (1,25). The training adherence of an athlete according to these factors is crucial in making any assumptions between training and performance. By keeping a training log, which records variables such as duration and overall intensity, a training load can be quantified.

The training load has been tested on competitive cyclists and speed skaters during twelve weeks of training (14). Index performances were recorded after six weeks of baseline training and six weeks of self-selected training increases. Performance improved from the six to twelve week period. RPE and load were the factors associated

with this significant change. It was found that total training *load* related best to performance variations. These results were best described with an individual specific log curve.

The speed skaters were tracked for a longer period of time through several different training interventions. Training load and performance were assessed using a rolling six-week average as a criterion measure. A regular relationship occurred when time trial performances were normalized to the minimal training load (500 units/week) level. It was acknowledged that during these controlled observations there was approximately a 10% improvement in performance for a 10-fold increase in training load (14). A stronger relationship exists in marathon runners (17).

The athletes in this study used a self-selected increase in training, which is normally dictated by professional coaches. Elite athletes and coaches tend to work with very structured training programs. The relationship between training load and performance along with the elite athletes competitiveness, leads to an increase in daily and weekly training loads. Coaches also believe that training more will improve performance, but if they ignore the day-to-day fatigue, athletes are more likely to overreach and develop performance incompetence or overtraining syndrome (21). When performance has declined, the first thought of most coaches is that the athlete is under-trained and therefore requires repeated days of intensified training.

Costill, Flynn, Kirwan, et al. (11) conducted a study involving highly trained male swimmers and the effects of repeated days of intensified training. Their typical training program included interval training (1.5 hours per day for 5 days per week) while

competing 1 day per week. During the experimental program the men swam twice per day, 1.5 hours in the morning and 1.5 hours in the afternoon. This represented a two-fold increase in their training load. Their average training distance was increased while intensity was maintained at 94% of their maximal oxygen uptake (VO_{2max}) for a ten successive day period. This intensified training regimen produced local muscular fatigue and resulted in difficulty in finishing the training sessions. Four of the twelve swimmers were unable to tolerate the heavy training and had to decrease their swimming speed to complete the workout.

A chronic, hard training program leads to inadequate recovery. A decline in performance or even the development of OTS may be seen if recovery days are not given or taken. At times recovery means a complete rest with no activity in order to let the body and muscles recover. It has been found that aerobic power (VO_{2max}) can be maintained with reduced exercise training of four days per week for a period of five weeks (27). When the primary goal of the athlete is to maintain their general fitness level, non-specific training is beneficial and can help to avoid training monotony (18).

A study by Lindsay and Colleagues (31) involved highly trained cyclists. They substituted a portion of their prolonged moderate intensity endurance training (BASE) with sustained, intense aerobic interval training. This four-week study of high-intensity interval training (HIT) resulted in 40-km time trial (TT_{40}) performance improvement and a peak power output (PPO) increase. The HIT program also exhibited a significant improvement in muscular resistance to fatigue. This "anaerobic" performance improvement was noted earlier in the study before improvements on TT_{40} and PPO.

Therefore, incorporating a program of interval training may lead to better adaptations in performance due to the fact that it allows for a recovery period (16,26).

Training Characteristics in the Development and Adaptation of Training

Training is still the major factor influencing the development of one's athletic performance level (36). Knowing that performance improves with training, the next step is establishing a well-planned training program. The intention of any training session is to stress the body so that the result is adaptation. The volume and intensity of a training regimen must be correlated to the stress-strain capacity of the athlete. Periods of intensive training can produce adaptive responses that ultimately lead to advanced athletic performance (33). The acute physiological effects of glycogen depletion and neuromuscular fatigue could limit short-term performance capacity. The purpose of this is to maximize the gains in the long-term physiological adaptations of training (e.g., lowered lactate level at trained intensity). During a taper period, the goal is to resolve the negative impact while maintaining the achieved physiologic adaptations leading to an optimal performance potential.

The training characteristics of intensity, volume and frequency have an influence on the adaptations in highly trained individuals. Mujika (33) has reviewed several studies which demonstrate that the magnitude of the adaptive responses depend upon these characteristics. The influence of training intensity is a major attribute to cardio-respiratory fitness. Intensity thresholds determined as moderate-intensity continuous training and high-intensity interval training produced different training adaptations. Moderate-intensity continuous training is more dynamic in enhancing muscle oxidative

capacity and delaying the accumulation of blood lactate during continuous exercise. On the other hand, high-intensity interval training produced greater increases in VO_{2max} , cardiac output and maximal exercise capacity. Mujika and colleagues (35) noted a positive correlation between the estimated mean training intensity during the season and the percentage improvement in performance during a follow-up period. The key factor was progressive increases in training intensity, which was consistent with performance improvements throughout the season.

The influence of training volume and frequency tend to have more significance in previously untrained subjects than in highly trained individuals (33). Wilmore and colleagues (38) incorporated a jogging program of either 12 or 24 min per day, 3 times per week for 10 weeks. The volume of 24 min per session elicited an improvement in cardiovascular variables to a greater degree. Performances in highly fit individuals require a higher training frequency to elicit a training response. At a trained level, to further increase VO_{2max} demands more training than maintaining it, since individuals have maintained VO_{2max} for a 15-week period of reduced training frequency (27).

The influence of taper duration has an impact on performance capabilities. Taper is defined as the period of reduced training prior to competition. This allows the negative training effects to dissipate and the positive training effects to increase the athletes' fitness level. Zarkadas and colleagues (39) showed a tapering of 4, 8, 10, 13 and 14 days elicited positive physiological and performance adaptations in cyclists and triathletes. Mujika and colleagues (34) used a marathon model to determine the optimal duration of taper. It was observed that 21 and 28-day tapers elicited a significant competition

performance improvement in highly trained swimmers. Therefore, a progressive taper period of 4-28 days can positively affect physiological and performance responses.

When an appropriate stimulus is applied to the physiological systems, an increase in functional capacity can be seen. This stimulus is called "stress" which leads to a response called "strain" (6). A theory proposing that environmental or physical stressors produce responses such as increased heart rate, blood pressure and serum concentrations of catecholamines and cortisol was developed by Selye in 1973 (37). This theory was represented by three stages in response to a stressor. The first stage, alarm reaction, mobilizes the systems in order to adjust to various stressors. An example used is the stress of running. The stress is supported by the strain of increasing oxygen transport through an augmentation of cardiac output along with redistribution of blood flow to active muscles (6). The body's capacity to adjust to a stressor in the future is enhanced by a reduced threat to homeostasis.

The second stage, resistance development, involves the body's capacity to improve physical conditioning. It is important to know an athlete's critical threshold to determine whether the physical training results in the desired training response. Various stressors are tolerated differently and are individualized in their adaptive response.

The third stage, exhaustion, is when the stress becomes intolerable. This can result in acute or chronic exhaustion. Forms of acute exhaustion are fractures, sprains and strains. Chronic exhaustion is also referred to as overtraining and involves stress fractures, emotional problems and a variety of soft tissue injuries. If an athlete has developed short-term overtraining during the season, a period of 2-3 regeneration weeks

may be necessary to return to their standard performance level. When long-term overtraining persists for 3-6 weeks, a longer regeneration period is required for complete resolution of symptoms (30).

A positive stressor of overload is expressed as load (intensity and duration), whereas a greater load results in greater fatigue and time needed for recovery (6). At times, the responses to stress are extended and adequate rest and recovery are implemented. Adaptations occur during this recovery period that are essential to the developing athlete.

A way to incorporate training to a peak, then allowing a reduced load prior to training for a new peak, is implied by the concept of periodization. This systematic planning of a training program focuses on the structure instead of the specific content (36). As early as the first Olympic games in Greece, an unrefined form of periodization was used (3). Modern theory and practice have allowed many coaches to help athletes achieve their performance potential.

Athletes' train in cycles that vary the volume and intensity of training to induce optimal improvements and allow the body to recover and rebuild. The 52 weeks of the training year are divided into phases of training called "macrocycles." The macrocycle includes a preparatory, competitive, and transition phase (36). Each week of training in a macrocycle is called a "microcycle." Four microcycles comprise a "mesocycle," which includes the ordinary, development, shock, and rehabilitation cycles. These function to control training stress by cycling the training load so that weeks of very high training

loads are followed by weeks of reduced load. The mesocycle building blocks provide structure in order to enhance the athlete's strategy for peaking at competition.

Many models of periodization exist for all different types of sports (24). An example of an endurance athlete's training schedule has three major phases (26). The first phase includes base/foundation training of prolonged (>60 minutes), moderate-intensity workouts during several months of the non-competitive period of a macrocycle. The next phase of transition involves 2-4 weeks of sustained exercise at the athlete's highest current steady state pace. The last phase of speed/power training over the final 14-21 days prior to competition includes running at speeds faster than the athlete's planned race pace.

By training in cycles, the athlete and coach can systematically plan sufficient workloads and adequate regeneration periods so that the necessary fatigue is not confused with being overtrained (23). Variations in periodization models to improve athletic performance enhance the working relationship between the athlete and coach. This takes into account the individuality and uniqueness of every athlete.

Support for the Contemporary Approach to the Monitoring of Training

To increase performance capacity an athlete must gradually increase intensity and volume of training. In the classic animal model study by Bruin and colleagues (7), it was discovered that overtraining could be induced through continually increasing training loads. An inability to complete the training session showed that there were insufficient rest periods. The recovery was not complete before the next training session and

premature fatigue hampered progress in training and competition. As long as exhaustive training is alternated with light training, adequate recovery can occur.

A quantitative indication of training load has been established and used in the development of appropriate training plans (18,19). By training too hard and not taking the proper recovery days, an athlete could experience performance incompetence or even OTS. This leads us to believe that the athlete is not properly executing the coaches designed training program. A log of training adherence and performance is beneficial for monitoring the interplay between athletes and coaches (20,29). By monitoring training, such as the taper period, a coach can deliberately peak the athlete for competition (28). The athlete and coach must be team oriented and goal driven to produce the optimal performance result. The purpose of monitoring training is to improve one's performance level and achieve world record performances.

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