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Chapter 8

Common Features in Overtrained Athletes and Individuals with Professional Burnout: Implications for Sports Medical Practice

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Abstract

In this paper, the authors discuss the symptoms of overtraining and burnout— two syndromes in which the etiology, after the decades of research, is still poorly understood. Overtraining is caused by an imbalance between exercise and rest, and often triggered by increased neuromuscular loading. There are no reliable diagnostic tests for overtraining. The neurological mechanisms underpinning burnout are similarly not known; however, it is generally accepted that the main cause is mental overloading. Both conditions are stress-related developmental processes suggesting malfunction of adrenal cortex and hypothalamus, mainly the pituitary. The two syndromes are also related to a variety of individual, environmental, and organizational factors. Based on the first author's extensive practical experience of working with overtrained athletes and individuals with occupational burnout, the authors draw on both literatures to offer invaluable insights into a medical assessment and treatment of athletes suffering from overtraining.

Keywords: Overtraining, burnout, POMS, sports medicine

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INTRODUCTION

Overtraining is defined as an imbalance between exercise and rest, occurring when athletes are subjected to an intensive training load without adequate rest and recovery. In addition to the physical effects, the overtraining syndrome manifests in simultaneous negative changes in the athlete's psychosocial environment. According to Budgett (1998), the overtraining syndrome is "a condition of fatigue and underperformance, often associated with frequent infections and depression which occurs following hard training and competition" (p. 107). Hence repeated physical exercises stimulate the metabolism and improve physical performance; yet long-lasting exercises may result in overtraining, with decreased performance and disturbances in organ functions. Athletes suffering from overtraining typically display irritation, carelessness, sleep disturbance, and frequent infections.

Biochemical indices of overtraining include high plasma cortisol and low testosterone, low responses of ACTH, cortisol and growth hormone to the insulin stimulation test, low salivary immunoglobulin and also decreased heart rate variation. Overtraining has been observed to lead to increased secretion of inflammatory cytokines, which offer an explanation for the syndrome's symptoms: tiredness, vulnerability to infection, and changes in hormonal secretions and the autonomic nervous system.

Work-related burnout shares many common features with overtraining. The concept of professional burnout was introduced by Freudenberger (1974) to describe exhaustion experienced by workers, suggesting that the predominant cause of burnout was mental stress. The most often cited definition of the burnout syndrome states that it is a psychological syndrome developed "in response to chronic interpersonal stressors on the job. The three key dimensions of this response are an overwhelming exhaustion, feelings of cynicism and detachment from the job, and a sense of ineffectiveness and lack of accomplishment" (Maslach, Schaufeli, and Leiter, 2001, p. 399). While most authors agree that stress is the key factor in the development of burnout, a comprehensive theoretical framework is still lacking (Schaufeli and Buunk, 2003) and the etiology of burnout is poorly understood.

Athletes affected by burnout likewise experience tiredness, poor concentration, decreased confidence and self-esteem, and sleep disturbance. Questionnaires, such as rating of perceived exertion (RPE; Borg, 1975), the recovery-stress questionnaire for athletes (RESTQ-Sport; Kellmann and Kallus, 2001) and the profile of mood states (POMS) questionnaire (McNair, Lorr, and Droppelman, 1971/1992) have been used in the analyses of overtraining and burnout. Yet there is very little available information about the roles of hormones, cytokines, and the autonomic nervous system in the development of burnout.

SYMPTOMS OF OVERTRAINING AND BURNOUT

Natural selection has led to strength and endurance as positive attributes in the evolution of *Homo sapiens*. However, in modern societies, these attributes relate primarily to sport and are no longer required in working life. Physical activity training improves an athlete's performance only to a certain extent. When the frequency and intensity of training exercises surpass this limit, the *condition of overtraining* will develop with long-lasting symptoms. Overtraining is preceded by an *overreaching condition*, which is a normal response to progressive overload. Overreaching is necessary for improved performance and the symptoms should cease within a few weeks of adequate rest. The development of both overtraining and burnout takes a long time, and recovery is likewise a lengthy process, often lasting several months. Diseases, such as infection and malnutrition, frequently hasten breaking out of the overtraining cycle. In addition to the impairment of an athlete's physical performance, other symptoms, such as carelessness, loss of appetite, and mood changes, are likely to occur. Though symptoms vary among individuals, sleep disturbances appear to be the most common (Kalimo and Toppinen, 1997; Winsley and Matos, 2011). Common symptoms of overtraining and burnout are summarized in Table 1.

Table 1. Common Symptoms of Overtraining and Burnout

Overtraining	Burnout
Physical performance impairs	Working capacity impairs
Tiredness	Tiredness
Irritability	Irritability
Sleep disturbances	Sleep disturbances
Sensitivity to infections	Sick absences
Cardiovascular changes	Cardiovascular changes
Hormonal changes	Inconclusive
Activation of inflammations	Inconclusive

Several studies have been done to reveal the etiology of overtraining, as well as to determine diagnostic methods (e.g., Green, Batada, Cole, Burnett, Kollias, McKay, et al., 2012; Xiao, Chen, and Dong, 2012). According to this research, the overtraining condition will develop fastest with an increase in volume of exercise (running distance or repetition of strength exercises), whereas an increase in intensity (running speed or load of strength exercises) has a noticeably smaller effect. For example, during a two-week training camp, featuring daily stepwise-increasing cycling tests, running of 40 minutes, and additional cycling of 60 minutes, an altered cardiovascular activity towards parasympathetic inhibition and sympathetic activation were observed (Baumert, 2006). In the absence of recovery, physical performance, oxygen uptake, and muscular strength will worsen. Exhaustion will follow from disturbances in muscle energy production and hormonal secretions. The final etiology of overtraining is not known, but physical exercise uncompensated for by adequate recovery markedly disturbs the hypothalamic neuroendocrine functions and the autonomic nervous system.

Work-related stress with symptoms of burnout is one of the most common occupational health problems. A European survey found that more than 60% of workers experience stress in their jobs for over 50% of the time (European Foundation for the Improvement of Living and Working Conditions, 1995/6). In Finland, approximately 7% of working population suffers from *severe* burnout (Kalimo and Toppinen, 1997), with main symptoms reported as tiredness, underestimation of working capacity, and weak self-confidence. Disruption of sleep is also common. Burnout is diagnosed largely through interviews and questionnaires. There is scant knowledge about the changes in organ function in individuals suffering from burnout. It is possible that work-related stress causes similar changes in the hypothalamic neuroendocrine system and autonomic nerves as does overtraining.

Athletic overtraining and professional burnout share several similar mental symptoms. In both situations, psychometric tests as diagnostic instruments are utilized. Heavy, excessive physical training is the major cause for overtraining, but has a minor role in the development of burnout. Whereas the continuation of heavy training is deleterious for overtraining athletes, light training may, on the contrary, prove beneficial for burnout individuals. At brain level, insensitivity of hypothalamic neuroendocrine neurons leading to suppression of stress hormones appears to be one diagnostic feature for overtraining symptoms, yet presently there exists no information about the role of hypothalamus in causing burnout. From a clinical point of view, comparisons between different psychometric tests used in the diagnosis of overtraining and burnout would be beneficial. In addition, measurements of blood concentrations of stress hormones would prove novel diagnostic tools in burnout subjects.

OVERTRAINING AND HORMONAL CHANGES

A single bout of heavy physical exercise immediately stimulates large parts of the endocrine system. Hormonal secretions from the pituitary and adrenal gland cortex will increase during the exercise and last for several hours. Increased cortisol levels mobilize glucose and fatty acids to muscle as a source of energy. On the other hand, the secretion of testosterone, an anabolic hormone responsible for increasing muscle protein synthesis and innervation, decreases after physical exercise (Adlercreuz, Härkönen, and Kuoppasalmi, 1986). For these reasons, anabolic compounds were previously used to improve recovery and to prevent the overtraining condition. The ratio of testosterone to cortisol concentration has been used as a marker, with a decrease of this ratio by 30% (or to smaller than 35×10^{-5}) suggesting overtraining. Some studies have, however, shown that the testosterone/cortisol ratio does not always provide an accurate prediction (Fry, Kraemer, and van Borselen, 1994; MacKinnon, Hooper, Jones, Gordon, and Bachmann, 1997). For instance, a squatting press-up exercise completed regularly for two weeks decreased maximal muscle strength by 11%, indicating an overtraining condition, yet testosterone, cortisol, and growth hormone levels did not change (Fry, et al., 1994). The authors therefore argued that reliance on the testosterone/cortisol ration as a sign of overtraining is not recommended.

Few studies on severe overtraining exist. In a South African study, overtraining was diagnosed in four male runners training for a marathon (Barron, Noakes, and Levy, 1985). They were tired, careless, did not sleep well, and their training volumes were lowering. Basal hormone levels were unchanged, with the exception of high cortisol levels. The functions of their neuroendocrine systems were studied by an insulin stimulation test. Responses of growth hormone, prolactin, ACTH, and cortisol to insulin were clearly decreased (Barron, et al., 1985). Recovery for the athletes lasted several months. The authors of this study recommend rest and light exercise for the prevention of overtraining symptoms if an increase of cortisol in the insulin test to below 180 nmol/l is observed.

In another study, three months of heavy endurance exercises resulted in the overtraining syndrome, with high cortisol, low testosterone, and low semen count (Roberts, McClure, and Weiner, 1993). Intensified endurance concentration in female athletes was found to decrease maximal oxygen uptake by 6% and lead to low adrenaline, noradrenaline, and cortisol responses to exercise – all signs of overtraining (Uusitalo, Uusitalo, and Rusko, 1998). Several recent studies have also focused on the effects of long-term exercise periods on the pituitary-adrenal and pituitary-gonad axes. An Iranian study showed that high intensity treadmill running for 24 weeks led to decreases in basal and stimulated testosterone, FSH and LH levels, but increased levels of sex hormone binding globulin, SHBG (Safarinejad, Azma, and Kolahi, 2009). LHR (GnRH) was used for the stimulation of LH and FSH for testosterone. Semen quality also worsened, and the authors concluded that overtraining has a deleterious effect on reproduction. The suppressed reproductive hormones returned following 12 weeks of detraining, suggesting that the overtraining was not grave.

Overtraining is preceded by overreaching conditions, and it is difficult to make a differential diagnosis between these syndromes. Usually, overtraining is distinguished by its duration, lasting, for instance, 6-12 months. For the purpose of analyzing these differences, ten underperforming athletes were studied using a two-bout exercise protocol, and ACTH, growth hormone, prolactin, testosterone, and lactic acid were measured after both sessions (Meeusen, Nederhof, Buyse, Roelands, de Schutter, and Piacentini, 2010). The first maximal test was performed at 9:00-10:00, followed by another at 14:00-15:00 on the same day. The authors were able to show that athletes with overtraining syndrome had suppressed ACTH and prolactin responses to the *second* exercise bout, but those with overreaching condition maintained normal responses. It would appear that in the overtraining condition, hypothalamic CRH-neurons become insensitive to glucocorticoids and are no longer capable of stimulating ACTH.

In an interesting study conducted with young men entering compulsory military service in Finland, cortisol, testosterone, SHBG, and lactic acid were monitored during an eight-week basic military training period (Tanskanen, Kyröläinen, Uusitalo, Huovinen, Nissilä, Kinnunen, et al., 2011). After the training period, one-third of conscripts had the overreaching condition, implied by high basal cortisol and SHBG, an unchanged testosterone/cortisol ratio, and low lactic acid response. The authors conclude that the basic training period is physically too demanding and recovery-type training should be implemented to avoid the development of overtraining. They further present cortisol, testosterone, and lactic acid response measurements as potentially useful tools to monitor training.

Heavy physical exercises have been observed to result in transient or long-lasting amenorrhea (Warren, 1992). The phenomenon is common in high-level endurance sportswomen, with 10-40% of female athletes as sufferers. It thus appears that hypogonadotrophic hypogonadism follows heavy exercises, perhaps due to the insensitivity of hypothalamic neurons to LRH. Female swimmers and cyclists appear to have less amenorrhea than endurance athletes (Sanborn, Albrecht, and Wagner, 1987). Amenorrhea is not specific to physical exercise, as moving to a new school in another country or repeated intensive heat exposures can also be causes, especially in young women (Leppäluoto, Huttunen, and Hirvonen, 1986). Physical exercise amenorrhea is treated with estrogen, which additionally protects from osteoporosis and stress fractures.

EXERCISE-INDUCED CARDIOVASCULAR RESPONSES

Heart rate has long been a measure for physical activity. New monitors can register the RR intervals and calculate heart rate variability from the intervals registered for several minutes (HRV). This is a noninvasive and effective method for studying the balance between sympathetic and parasympathetic tone. HRV changes have been traced both during and after physical exercises, and then related to the changes in physical performance or to the development of overtraining. Orthostatic heart rate responses have likewise been used for estimating the effects of training. Heart rate and HRV are measured in supine and standing positions – blood pressure can also be measured at this time. Findings which relate to overtraining are increased heart rate, slow recovery during standing, and smaller HRV. More specifically, an increase of 6% or higher in heart rate and a 25% decrease in HRV suggests overtraining (Uusitalo, Uusitalo, and Rusko, 2000). HRV responses should be tracked when athletes are relocating to distant training camps or going to competitions. Full-scale training can begin after HRV responses have returned to normal levels.

Endurance training increases high-frequency power domain in HRV recordings, which is known to reflect parasympathetic activity. Increases in that domain correlates positively to maximal oxygen uptake (Uusitalo, et al., 1998, 2000). Overtraining athletes had decreased HRV, meaning a shift from parasympathetic to sympathetic activity. In another study, in which HRV was studied in severely overtraining athletes during night sleep and after awakening, similar findings were obtained (Hynynen, Uusitalo, Konttinen, and Rusko, 2006). No changes in heart rate and HRV were found during sleep, but after waking, overtraining athletes exhibited variation in heart rate and the low-frequency domain in HRV was lower than in their healthy peers, indicating an increase of sympathetic tone and a parasympathetic withdrawal. However, HRV recordings show great inter-individual differences, problematizing their use in overtraining diagnoses. It is not known whether HRV recordings can be applied to evaluate work-related burnout conditions.

PHYSICAL EXERCISE AND IMMUNE SYSTEM

Moderate levels of physical activity have been observed to decrease the occurrence of upper airway infections, but intensive activity appears to have the opposite effect, sensitizing top-level athletes in particular to infection (Nieman, Nehlen-Cannarella, and Henson, 1998; Nieman and Pedersen, 1999). Long-lasting heavy physical exercise impairs the response of the immune system (see Table 2): activity of white blood cells and lymphocytes is suppressed and cytokines may activate or inhibit inflammatory reactions. Furthermore, physical exercise induces the secretion on tumor necrosis factor alpha (TNF-α), interleukines 1b, 6, 10, and IL-1 receptor antagonist (Nieman, et al., 1998; Stensberg, van Hall, and Osada, 2000).

Table 2. Heavy Physical Exercise-induced Immune System Response

Immune Reactions
Increased neutrophil count, lymphopenia (cortisol effect)
Increased phagocytosis
Decreased oxidative activity in granulocytes
Decreased activity of natural killer cells and T-cells
Delayed skin hypersensitivity
Increased release of proinflammatory cytokines (TNF-α, IL-1, IL-6)
Increased release of anti-inflammatory cytokines (IL-1 receptor antagonist, soluble TNF receptors, IL-4)
Decrease of salivary immunoglobulin A

Cytokines prove interesting in the development of overtraining. Interleukine 6 (IL-6) presents a dramatic, over-100-fold increase after marathon running (Ostrowski, Rohde, and Asp, 1999), yet moderate exercises (e.g., cycling for 60 minutes at 60% level of the maximal oxygen uptake) do not have any effect on plasma IL-6 levels (Smith, 2000). Heavy exercises do not always lead to inflammations, as the release of anti-inflammatory cytokines increases accordingly.

Cytokines are released through blood cells, but muscle and fat cells also produce them. Muscle cells contain IL-6 messenger RNA, which increases in response to training (Ostrowski, Rohde, and Zacho, 1998). IL-6 has pleiotropic effects, inducing the secretion of lGF-1, C-reactive protein, and glucose from the liver (Tsigos, Papanicolaou, Kyrou, Defensor, Mitsiadis, and Chrousos, 1997).

During heavy exercise, muscle glycogen stores diminish and increased IL-6 levels have compensatory effects, increasing glucose release from the liver. Cytokines also affect the central nervous system, potentially resulting in the tiredness, feeling sick, and negative mood states observed as symptoms of the overtraining condition.

Recently, studies have shown that physical exercise causes inflammatory damages in muscle cells and increases the release of pro-inflammatory cytokines from muscle and blood cells (Xiao, et al., 2012). At the same time, anti-inflammatory cytokines are released to limit the inflammation. Cytokines further affect the hypothalamus by stimulating the secretion of ACTH (Paulsen, Mikkelsen, Raastad, and Peake, 2012), which may relate to the activation of the general stress reaction in response to heavy physical exercise.

Besides inflammation and cytokine release, heavy exercises can cause muscle damage (myofibre ruptures). During a recovery phase, some muscle precursor cells called satellite cells accumulate in the damaged area and produce new fibers. Overtraining causes large muscle damages and the recovery may last for weeks. Anti-inflammatory steroids delay this exercise induced muscle recovery (Paulsen, et al., 2012).

Prevention of Overtraining and Burnout

Athletic overtraining denotes an imbalance between training and recovery, and it is evident that the best training responses are achieved at high intensity levels, bordering on those which lead to overtraining. Athletes’ responses to training load, competition and life stressors are idiosyncratic and vary through the season; therefore, training must be individualized taking multiple factors into account. While individuals participating in physical exercise for recreation or for health purposes would benefit keeping track of workouts, training results, and diseases in a training diary, it is an absolute must for competing athletes. The diaries will monitor the training progress and alert to the possible development of overtraining.

There are several questionnaires which monitor an athlete’s training level and can be used in the prevention of overtraining. The most familiar are rating of perceived exertion (RPE; Borg, 1975), profiling mood states (POMS; McNair, et al., 1971/1992), and the recovery-stress questionnaire for athletes (RESTQ-Sport; Kellmann and Kallus, 2001). The results of the questionnaires can be accompanied by body measures (e.g., weight), and heart rate monitoring is very useful when endurance level information is important. Training can be followed and adjusted according to the results of the monitoring. For detecting sleep disorders, a wrist activity monitor can be used. Since the occurrence of infections, anemia, and thyroid diseases are often associated with overtraining, medical check-ups are necessary. There is no simple test or method by which overtraining and its development can be diagnosed, but the combination of biochemical and physiological measurements to the results of questionnaires should provide sufficient information about the condition.

In Finland, a large-scale study of professional burnout was conducted by Kalimo and Toppinen (1997) revealing that work-related burnout was associated with long working hours, the uncertainty of employment, underestimation of own labor input and ageing. The authors developed a 16-item questionnaire to investigate an employee's experience, tiredness, and interest and motivation to work. The answers are then quantified and form an index, increases of which imply burnout. In this method, the questionnaire provides insight into an individual's mental state, and can be utilized for the prevention of the burnout condition.

APPLYING RESEARCH IN PRACTICE: A CASE OF OVERTRAINING

As already discussed, it is very difficult to distinguish between overreaching and the overtraining syndrome. The first author of this paper has been working with several Finnish teams in their preparation for the Olympic Games. The POMS questionnaire proved to be useful in identifying athletes at a state of overreaching or overtraining, allowing for an intervention to prevent athletes' overreaching turning into the overtraining.

The standard POMS scale consists of 65 questions, which form scores for five negative and one positive item: tension-anxiety, depression-rejection, anger-hostility, fatigue-inertia, confusion-bewilderment, and vigor-activity. Successful performance in sport is usually associated with an "iceberg profile" (Figure 1), described by Morgan, Brown, Raglin, O'Connor, and Ellickson (1987) in their study of mood states observed in swimmers. In the "iceberg" profile assessed by POMS, vigor index is high while tension, depression, anger, fatigue, and confusion indices are low. Athletes suffering from overreaching or overtraining syndrome form an opposite POMS image.

The summary of the five negative POMS items minus vigor can be composed as TMS (total mood score), and the ratio of POMS vigor to POMS fatigue can be used as an energy index (Kenttä, 2006). POMS has been routinely used in our medical clinic to screen for burnout or overtraining syndrome, as well as during the follow-up on the healing process of these conditions. It can likewise be used in order to determine the state of health when performing health examinations for athletes or working people, and when observing the influence of a training program.

The POMS scale is well documented and easy to fill out, and the results can be attained instantly. It is useful both in observation of a single individual or of a group of people. Therefore, it can be applied to analyze the condition of an athlete or an employee, a team, working department, or even a whole company.

When the Finnish Olympic swimming team had a strenuous training weekend, we used POMS to observe the training effect and recovery. The scale was filled three times (i.e., three days before, during, and three days after the camp). The changes in the energy index of the team showed that both the training effect and the recovery were good, and hence further trainings could be planned according to this information (see Figure 2).

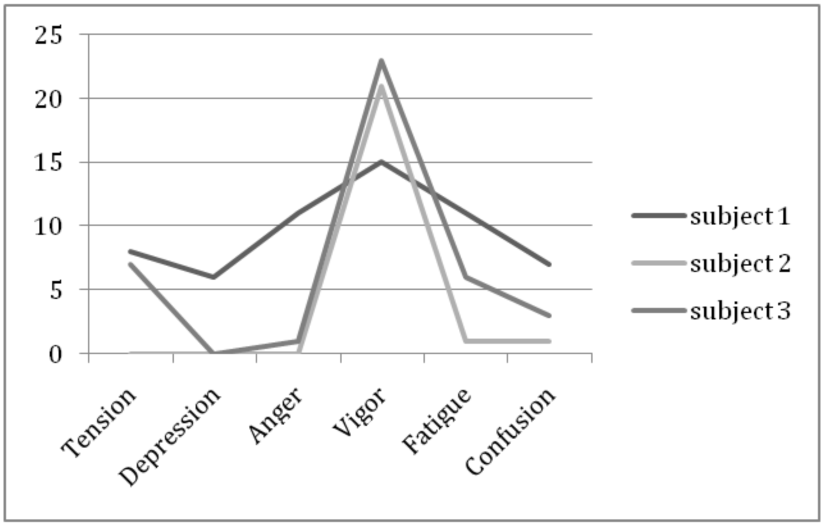

Figure 1. The "Iceberg Profile" of POMS Results in Three Healthy Athletes.

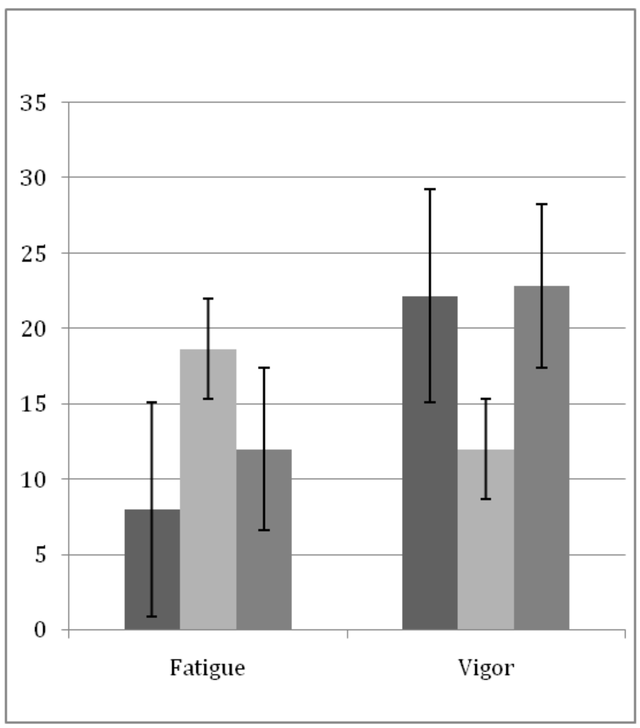

Figure 2. The Energy Index Changes of a Swimming Team Before, During and After a Strenuous Training Camp.

In another example, the Finnish Olympic judo team was abroad for a training camp when we received a phone call from the very concerned head coach and an e-mail from one of the athletes claiming "It's not working now". A preliminary review of the athlete revealed many symptoms associated with overtraining, such as exhaustion, muscle fatigue, and insomnia. No signs of infections were found.

Overtraining or overreaching was the possible diagnosis. To investigate further, a POMS questionnaire was sent by and replied to via e-mail. Total mood score and energy index were alarmingly abnormal. The athlete was advised to halt all training and competitions until further notice to allow full recovery. The questionnaire was filled in the beginning of the resting period and repeated monthly for follow-up. After four months of complete break, the total mood score (TMS) reflected the recovery (Figure 3). The athlete gradually returned to training and began to enter competitions, eventually qualifying for the London Olympics.

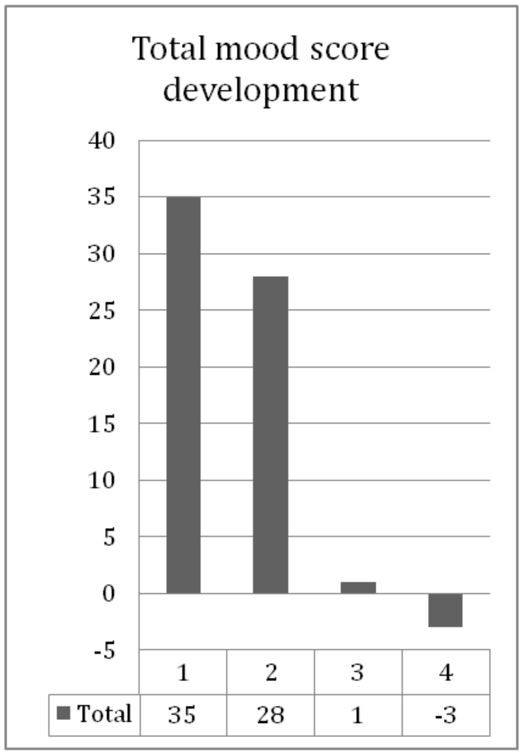

Figure 3. Total Mood Score Development of an Overtrained Athlete During Recovery. (Numbers 1-4 indicate months).

CONCLUSION

Overtraining and burnout share many common symptoms, such as decreased performance, tiredness, sleep disturbance, carelessness, and sensitivity to infection. There is no single test for diagnosing professional burnout or overtraining syndrome. Burnout is assessed primarily through the use of questionnaires, but biochemical analyses might give important information about occupational stress and burnout mechanisms. In athletic overtraining, hypothalamic neuroendocrine functions are disturbed, sympathetic tonus is increased, and inflammatory factors possibly activated. It is not yet known how various factors (e.g., psychological, physiological, immunological) play a role in preventing athletes’ recovery from training and competition. Considering the amount of factors shared between the two conditions, it is possible that even moderate exercise may worsen severe burnout.

In our experience, POMS is a practical tool when monitoring health condition, recovery, or the effects of training. The results are most valuable when observing the development of physical conditions of one person or a group of athletes over a period of time (having repeated measures of the POMS questionnaire) rather than drawing conclusions after a single visit. Clinical diagnoses of underperforming athletes remain to be based mainly on the athletes' medical history. In order to make the overtraining syndrome diagnosis, the physician needs to be able to rule out other underlying medical causes and to gather suitable results from questionnaires and physical tests.

REFERENCES

Adlercreutz H., Härkönen M., and Kuoppasalmi K. (1986). Effect of training on plasma anabolic and catabolic steroid hormones and their response during physical exercise. *International Journal of Sports Medicine, 7,* Suppl 1, 27-8.

Barron, J. L., Noakes, T. D., and Levy, W. (1985) Hypothalamic dysfunction in overtrained athletes. *Journal of Clinical Endocrinology Metabolism, 60,* 803-806.

Baumert, M., Brechtel, L., Lock, J., Hermsdorf, M., Wolff, R., Baier, V., and Voss, A. (2006). Heart rate variability, blood pressure variability, and baroreflex sensitivity in overtrained athletes. *Clinical Journal of Sport Medicine, 16,* 412-417.

Borg G. (1975). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitative Medicine, 2,* 92-98.

Budgett, R. (1998). Fatigue and underperformance in athletes: the overtraining syndrome. *British Journal of Sports Medicine, 32,* 107-110.

European Foundation for the Improvement of Living and Working Conditions (1995/6). *Second European Survey on Working Conditions – Working Conditions in the European Union.* Luxemburg: Office for Official Publications of the European Communities.

Freudenberger, H. J. (1974). Staff burnout. *Journal of Social Sciences, 30,* 159-165.

Fry, A. C., Kraemer, W. J., and van Borselen. (1994). Performance decrements with high-intensity resistance overtraining. *Medicine and Science in Sports and Exercise, 26,* 1165-1173.

Green, H. J., Batada, A., Cole, B., Burnett, M. E., Kollias, H., McKay, S, et al. (2012). Muscle cellular properties in the ice hockey player: a model for investigating overtraining? *Canadian Journal of Physiology and Pharmacology, 90,* 567-578.

Hooper S. L., MacKinnon, L. T., Gordon, R. D., and Bachmann, A. W. (1993). Hormonal responses of elite swimmers to overtraining. *Medicine in Science of Sports and Exercise, 6,* 741-747.

Hynynen, E., Uusitalo, A., Konttinen, N., and Rusko, H. (2006). Heart rate variability during night sleep and after awakening in overtrained athletes. *Medicine and Science in Sports and Exercise, 38,* 313-317.

Kalimo, R., and Toppinen, S. (1997). Työuupumus Suomen työikäisellä väestöllä. Kirjassa: Työuupumus Suomen työikäisellä väestöllä. Työterveyslaitos, Helsinki, s. 1-63.

Kellman, M., and Kallus, K. W. (2001). *The recovery –stress questionnaire for athletes; user manual.* Champaign, IL, USA: Human Kinetics.

Kenttä, G., Hassmén, P., and Raglin, J. S. (2006). Mood state monitoring of training and recovery in elite kayakers. *European Journal of Sport Science, 6*, 245-253.

Kreher, J. B, and Schwartz, J. B. (2012). Overtraining syndrome: a practical guide. *Sports Health, 4*,128-138.

Leppäluoto, J., Huttunen, P., and Hirvonen, J. (1986). Endocrine effects of repeated sauna bathing. *Acta Physiologica Scandinavica*, *128*, 467-470.

MacKinnon, L. T., Hooper, S. L., Jones, S., Gordon, R. D., and Bachmann, A. W. (1997). Hormonal, immunological and haematological responses to intensified training in elite swimmers. *Medicine and Science in Sports and Exercise, 29*, 1637-1645.

Maslach, C., Schaufeli, W. B., and Leiter, M. P. (2001). Job burnout. *Annual Review of Psychology, 52,* 397–422.

McNair, D., Lorr, M., and Droppelman, L. F. (1971/1992). *Profile of mood states manual*. San Diego: Educational and Industrial Testing Service.

Meeusen, R., Nederhof, E., Buyse, L., Roelands, B., de Schutter, G., and Piacentini, M. F. (2010). Diagnosing overtraining in athletes using the two-bout exercise protocol. *British Journal of Sports Medicine, 44,* 642-648.

Morgan, W. P., Brown, D. R., Raglin, J. S., O'Connor, P. J., and Ellickson, K. A. (1987). Psychological monitoring of overtraining and staleness. *British Journal of Sports Medicine, 21,* 107-114.

Nieman, D. C., and Pedersen, B. K. (1999). Exercise and immune function. Recent developments. *Sports Medicine, 27*(2), 73-80.

Nieman, D. C., Nehlen-Cannarella, S. L., and Henson, D. A. (1998). Immune response to exercise training and/or energy restriction in obese women. *Medicine and Science in Sports and Exercise, 30,* 679-686.

Ostrowski, K., Rohde, T., and Asp, S. (1999). Pro- and anti-inflammatory cytokine balance in strenuous exercise in humans. *Journal of Physiology, 515*, 287-291.

Ostrowski K., Rohde, T., and Zacho, M. (1998). Evidence that interleukin-6 is produced in human skeletal muscle during prolonged running. *Journal of Physiology, 508*, 949-953.

Paulsen, G., Mikkelsen, U.R., Raastad, T., and Peake, J.M. (2012). Leucocytes, cytokines and satellite cells: what role do they play in muscle damage and regeneration following eccentric exercise? *Exercise Immunology Review, 18*, 42-97.

Roberts, A. C., McClure, R. D., and Weiner, R. I. (1993). Overtraining affects male reproductive status. *Fertility and Sterility, 60*, 686-692.

Safarinejad M. R., Azma K., and Kolahi A. A. (2009). The effects of intensive, long-term treadmill running on reproductive hormones, hypothalamus-pituitary-testis axis, and semen quality: a randomized controlled study. *Journal of Endocrinology, 200*, 259-271.

Sanborn C. F., Albrecht, B. H., and Wagner, W. W. (1987). Athletic amenorrhea: lack of association with body fat. *Medicine and Science in Sports and Exercise*, *19*, 207-211.

Schaufeli, W. B. and Buunk, B. P. (2003). Burnout: an overview of 25 years of research and theorizing. In M. J. Schabracq, Winnubst, J. A., and Cooper, C. L. (Eds.). *Handbook of work and health psychology* (pp. 383 – 425). Chichester: Wiley.

Smith, L. L. (2000). Cytokine hypothesis of overtraining: a physiological adaptation to excessive stress? *Medicine and Science in Sports and Exercise, 32*, 317-331.

Stensberg, A., van Hall, G., and Osada T. (2000). Production of interleukin-6 in contracting human skeletal muscles can account for the exercise-induced increase in plasma interleukin-6. *Journal of Physiology, 529*, 237-242.

Tanskanen, M. M., Kyröläinen, H., Uusitalo, A. L., Huovinen, J., Nissilä, J., Kinnunen, H,. et al. (2011). Serun sex hormone-binding globulin and cortisol concentrations are associated with overreaching during strenuous military training. *Journal of Strength and Conditioning Research, 25*, 787-797.

Tsigos C., Papanicolaou, D. A., Kyrou, I., Defensor, R., Mitsiadis, C. S., Chrousos, G. P. (1997). Dose-dependent effects of recombinant human interleukin-6 on glucose regulation. *Journal of Clinical Endocrinology and Metabolism, 82*, 4167-4170.

Uusitalo A. L., Uusitalo A. J., and Rusko, H. K. (1998). Exhaustive endurance training for 6-9 weeks did not induce changes in intrinsic heart rate and cardiac autonomic modulation in female athletes. *International Journal of Sports Medicine, 19*, 532-540.

Uusitalo A. L., Uusitalo A. J., and Rusko, H. K. (2000). Heart rate and blood pressure variability during heavy training and overtraining in the female athlete. *International Journal of Sports Medicine, 21*, 45-53.

Warren M. P. (1992). Clinical review 40. Amenorrhea in endurance runners. *Journal of Clinical Endocrinology and Metabolism, 75*, 1393-1397.

Winsley R., and Matos N. (2011). Overtraining and elite young athletes. *Medicine in Sport Science, 56*, 97-105.

Xiao W., Chen P., and Dong J. (2012). Effects of overtraining on skeletal muscle growth and gene expression. *International Journal of Sports Medicine, 33*, 846-853.