THE ROLE OF LEPTIN IN MONITORING TRAINING LOADS DURING ROWING: A SYSTEMATIC REVIEW

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Abstract:

Objective: In competitive sports, too small or too large loads lead to poor sports results. Situation of overload are particularly dangerous to the body, which may lead to overtraining. In this work, the literature on the possibility of assessing training loads with the use of leptin concentration measurement in men and women practicing rowing was analysed.

Materials and methods: A systematic review was performed using the Scopus, Pubmed and Google Scholar databases between 1995-2020. After an initial analysis of 56 articles and taking the analysed topics into account, 25 articles were included in this review. As part of the review, data for 75 rowers were analysed. The usefulness of leptin - a hormone produced by adipose tissue - as a marker of training loads in several sports disciplines, with particular emphasis on rowing, was evaluated. Within this context, the role of leptin may be to control these loads due to its relatively high sensitivity in response to increases in training intensity or volume. The presented general characteristics of rowing and the physiological basis of exercise are the background for considerations on the possibility of using leptin as a burden marker in this discipline.

Results: Due to the fact that the concentration of leptin correlates with the content of adipose tissue and BMI (Body Mass Index), its changes may inform about training loads directly related to the amount of energy expenditure. A review of the literature from the last 25 years, i.e. from the moment when this hormone was discovered, allowed to formulate the thesis that leptin may be a marker of training loads, however, determining its concentration makes sense when the same factors that may affect its secretion are taken into account each time.

Conclusions: Training in rowing, that involves high training loads, causes significant changes in blood leptin levels. Training periods with high exercise load, associated with a significant increase in energy expenditure, lead to a decrease in resting leptin concentration, while periods with less load increase it. The main factor determining changes in leptin concentration during training is the amount of energy expenditure, which in the case of rowing involving very large muscle groups, is very high. Although the amount of energy expenditure in training, leading to a decrease in leptin concentration is difficult to determine, the energy expenditure cannot be less than 800 kcal in a single training unit.

Introduction

Leptin concentration is related to the composition of human body mass, and more specifically, to the amount of adipose tissue by which it is secreted. The discovery of a defect in the ob (obese) gene in 1994 made it possible to link the development of obesity in mice with the presence of this hormone in the blood. Since then, intensive research has been initiated on the relationship between leptin, body mass and body fat content. Later, the focus was also on its potential role as a marker of training loads in sport.

Physiologically, leptin is involved in the regulation of body mass by influencing the activity of the hunger
and satiety centre located in the hypothalamus. Its secretion also depends on the body’s energy balance [1]. This hormone, produced by adipocytes, may be a good marker of training loads in both single efforts and the entire training process [2]. Due to the high proportion of muscle tissue and the usually low content of adipose tissue in competitive rowers, leptin may be a useful index regarding control of the training process in rowing [3,4]. As a result of rowing movement biomechanics, the great participation of muscle groups and the specificity of the discipline, high energy expenditure is generated by representatives of this discipline. As a result, it affects the energy balance of the body and the regulation of food intake. Unfortunately, the discrepancies in many studies regarding the impact of a single effort and training on the concentration of leptin [5,6], which may result from the different training loads applied, the duration of exercise and the content of adipose tissue force the comparison of absolute values in representatives of disciplines with identical or similar exercise characteristics.

Since 1900, rowing has been a discipline included in the programme of the Olympic Games, in which there are 7 competitions for men and women. The rowing regatta takes place over a distance of 2,000 m for both sexes, and each of the crews (settlements) goes on its own track, marked with buoys. The race duration, depending on the competition, ranges from 5 minutes (eights with the helmsman) to about 8 minutes (ones, skiff). Each race consists of 3 main phases (start, track race, finish), during which the metabolic and energetic processes take place differently. It is an endurance-strength sport discipline in which the basis of training is aerobic [7]. However, due to the nature of the effort (the need to overcome external resistance) and its duration, endurance-strength and muscular strength also play an important role. In rowing efforts, due to their duration (more than 5 minutes), ATP (adenosine triphosphate) resynthesis in the muscles, mainly occurs in non-oxygen energy transformations [8]. Roth et al. [9], on the basis of research with the use of a simulated rowing race, found that 67% of energy is supplied from aerobic energy processes, and in 33%, from anaerobic processes. On the other hand, Hartmann and Mader [10] reported that aerobic processes (80%), compared to those anaerobic (20%), contribute to total ATP re-synthesis. Despite these differences, it is assumed that endurance training, supported by strength training, as well as the development of anaerobic endurance – is the basis of rowing training [11].

General training and training process in rowing are divided according to the classic rules proposed by Matvejev [12] into the following periods: preparation, competition and transition. Rowing, as a summer discipline in which the most important championship events are held in the months from May to September, forces the construction of a specific training plan in a way that allows to achieve top form for the main competitions of the season, such as the World Championships or the Olympic Games. The main feature of rowing, in relation to the annual training plan, is that training on the water takes place for about 6-7 months, while in the rest of the year, athletes focus on preparing sports form by introducing various types of training, taking other sports disciplines into account.

Tab. 1. Ways and possibilities of monitoring the course of the training process in rowing (own analysis).

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SHBG (sex hormone-binding globulin) – sex hormone binding protein; IGFBP-3 (insulin-like growth factor binding globulin-3) – insulin-like growth factor I; * Leptin is not a standard parameter in monitoring training loads, but based on the analysis of literature carried out in this study, it can be proposed as such an indicator in rowing.
In competitive sports, in order to assess the state of training and monitor training loads, it is recommended to determine as many parameters as possible [11,13], which provide more information on the athlete’s reaction to the applied training programme. The key factors in assessing the effectiveness of the conducted training are regular (every 3-4 months), repeated tests of physical fitness and specialised exercise tests for a given sports discipline. Permanent reduction of exercise capacity (e.g. worse results for tests or sports results), despite continued training, suggests fatigue, which may develop into overtraining syndrome (OTS). In order to confirm the presence of fatigue or overtraining in athletes with such symptoms, specific biochemical and hormonal tests are performed that may confirm the occurrence of overtraining.

Among the biochemical markers already well-established in sport, testosterone and cortisol, as well as their relationship with each other, are most often mentioned [14]. Moreover, decreases in the ratio of free testosterone to cortisol and insulin-like growth factor-1 to cortisol were indicated as good indices of the applied training loads [15]. Recently, more and more information, especially within the context of monitoring training in rowing, concerns another hormone – leptin, the level of which depends on the content of adipose tissue (which often changes during a long-term training process) and the amount of energy expenditure during a single exercise session and during the whole training programme. With this in mind, leptin seems to be a good candidate as another training load indicator.

Leptin as a regulatory hormone in the energy metabolism of the body

Leptin was discovered in 1994 during research on mice [16], and shortly afterwards, it was proved that it is a product of the ob obesity gene located in humans on chromosome 7q 31.3 [17]. Leptin is a protein composed primarily of 167 amino acids, produced mainly by fat cells (adipocytes) of white adipose tissue [16], showing pleiotropic effects. It has impact on metabolism, neuro-hormonal changes and the functioning of the immune system. Leptin is also secreted in smaller amounts by chorionic cells in the human placenta, stomach, hypothalamus and skeletal muscles [18] as well as neoplasms of neuroblastic origin [19].

The action of leptin depends on many factors, including the way it affects a specific leptin receptor called OB-R (LEPR) and its 5 isoforms [20]. Of all the forms, the most important function is played by the OB-Rb receptor, which, due to its leptin-binding sites and cellular trans domain, serving interaction with Janus kinase (JAK) and STAT3 signalling proteins, activates the JAK-STAT pathway, which is the main signalling pathway inside the cell [21]. The pathway containing the STAT3 protein is involved in maintaining the energy homeostasis of the body by regulating body mass and tissue resistance to insulin and leptin [22]. According to current knowledge, only the long isoform of the OB-Rb leptin receptor, which is most expressed in the hypothalamus, i.e. the food centre of hunger and satiety in the brain, plays a functional role in the regulation of body mass. Antagonistic centres located in the nuclei of the hypothalamus influence food intake and regulate the energy resources of the system. In these processes, one of the key roles is played by leptin, which by signalling the nutritional status (which takes place thanks to, among others, the central inhibition of the synthesis of another hormone – ghrelin), helps to ensure the proper energy balance of the body. Leptin also affects other tissues via the peripheral nervous system.

Research methodology

As part of the preparation of the work, the international literature published in PubMed Medline, Scopus and Google Scholar was analysed.

Results and Discussion

Leptin in single efforts and in training various sports

In many studies, the effect of a single effort on the concentration of leptin is not clear. The factors that determine the size of the changes are duration, intensity and type of effort, as well as the athlete’s body structure. It seems that the most important are the duration and intensity of exercise, which determine the amount of energy expenditure.

The first study in which it was suggested that energy expenditure is important in the regulation of human leptin levels was that by Leal-Cerro A et al. [23]. It was shown its level in a marathon run, amounting to 2,800 kcal, corresponds to a significant decrease in leptin concentration. This path was followed by Zaccaria et al. [1], who linked the amount of energy expenditure with the change in leptin concentration. It turned out that its decrease was recorded only in the case of a ultramarathon effort and during a 45-km alpine-ski race, while in the case of competitors who ran the half-marathon, the concentration of leptin did not change. Obviously, these efforts were characterised by large discrepancies in the size of energy expenditure, which in the case of the ultramarathon totalled 7,000 kcal. As the amount of energy expenditure in the half-marathon effort reached 1,400 kcal, it can be expected that the decrease in leptin concentration will take place only in those efforts where the energy expenditure will be higher.
This was also confirmed by an experiment comprising a long-lasting effort, i.e. 8.5 hours. (25-km swimming marathon), which was associated with a 50% decrease in leptin, but also a 40% increase in neuropeptide Y (NPY) [24]. Knowing that leptin inhibits the hypothalamic secretion of NPY and thus, the feeling of hunger, the observed change will lead to an increase in food intake and equalisation of energy balance, while in studies conducted among cyclists, it was observed that for a change in leptin concentration to occur, the amount of one-time energy expenditure must be over 800 kcal [25,26].

Similarly, in research on rowers, a 20% decrease in the concentration of leptin and visfatin was observed after 2-hour training on water and in normal conditions, which generated an expenditure of 1,200-1,500 kcal [27,28], which is consistent with the theory that it is the amount of energy expenditure that is of greatest importance for the secretion of the hormone after a single effort.

In the context of monitoring training loads, the role of leptin, especially in long-term training programmes, is also not fully understood. Long-term endurance physical training usually leads to significant changes in body build, i.e. a decrease in total body mass, BMI, reduction of adipose tissue and an increase in lean body mass [29]. In research, it has been shown that the concentration of leptin is positively correlated with adipose tissue content [30], and this relationship has also been confirmed in training [31].

The results of research conducted by Haluzik allow to confirm that the low body mass of athletes (race-walkers) is associated with a lower concentration of leptin. At the same time, however, the results obtained for this research group suggest that the amount of adipose tissue is not the only factor determining the concentration of leptin in the blood, because the similar content of adipose tissue in athletes from other disciplines (rugby players) compared to non-training individuals was also associated with differences in leptin concentration [32]. However, the content of adipose tissue was determined in this research by using the measurement of skin-fat folds, which does not provide complete information on the amount of visceral fat essential for the concentration of leptin in the blood [32]. Nonetheless, the relationship between the content of adipose tissue and the concentration of leptin was also not demonstrated in the study by Casmiro-Lopes et al. [33], carried out on judo players. Despite comparable training loads over a period of 10 months and a significantly higher body fat content in women (BF: 14.3 kg in women; B:F 5.5 kg in men), the differences in the level of leptin between these groups were not significant (5.9 ng/ml in women; 5.4 ng/ml in men). The authors concluded that these results may be related to differences in the distribution of fat mass in the subcutaneous or visceral tissues and in the secretion of leptin by these tissues [34]. Doubts about the relationship between the concentration of leptin and the content of fat in the body were also raised in the work by Hickey et al. [35], in which it turned out that in women, the concentration of leptin is higher than in men, but this was independent of the amount of adipose tissue.

Despite the lack of clear confirmation concerning the existence of a close relationship between the concentration of leptin and the amount of adipose tissue in athletes, endurance training most often leads to a decrease in the concentration of this hormone in the blood [3,36]. Changes in leptin concentration following training seem to have a similar basis with regard to changes in this hormone in response to a single exercise session. Decreased leptin concentration was observed both after shorter [2,3] and longer training programmes [36, 37]. Moreover, lower resting concentration of this hormone was found in athletes representing various sports compared to non-training participants [29,38]. This situation applies to athletes of endurance [31], strength [38] and team sports [39] competitions.

**Leptin as a marker of training loads in rowing**

Training changes in leptin concentration are related to the amount of training loads applied. For example, in the work by Baylor and Hackney [40], 17 rowers training at a university sports club were tested. During the 20-week training period, up to the 10th week, loads of submaximal and maximal intensity were applied, while the other half of the time comprised a period in which the loads were moderate. Leptin levels decreased by 26% after week 5 and a further 28% after week 10 of the training programme, while for the last measurement at week 20, leptin levels returned to baseline. Interestingly, in this research, many female athletes (n=7) did not demonstrate any leptin or thyroid axis hormone (fT3 and TSH) responses to the applied training loads (non-responders), but the mechanism for this is not fully-known.

Similar conclusions were drawn by Ramson et al. [41], who during the shorter training period of rowers (4 weeks), characterised by an 45% increase (the first 3 weeks), and later a decrease by 40% (the last week), recorded adequate differences in leptin concentration (i.e. an initial decrease and then an increase towards baseline values) to these changes. The relationship of training volume to leptin fluctuations after a single exercise bout was reported in other studies by the same author. During the 4-week training of rowers, it was observed that in the period with the highest training volume (at the end of week 3), after a 2-hour rowing effort in 80% HRTP water, a decrease was noted in leptin concentration immediately after and 30 minutes following its completion. At that time, a significantly different energy balance was found, caloric
intake was recorded at 4,879 kcal/day, while the energy expenditure was 5,329 kcal/day, which resulted in negative energy balance and reduced leptin secretion [42].

Interesting data were provided in the study by Hickey et al. [35], suggesting that the initial level of physical fitness of the examined persons may also be important for the changes in leptin concentration. When it is lower, relatively low training loads can lead to significant changes in leptin secretion. In this study, the participants were non-training persons with VO2max levels below 30 ml/kg/min, indicating a low level of exercise capacity. During the 12-week training with loads dominated by oxygen energy (4 training sessions a week, 30-45 minutes each), a significant decrease was noted in leptin concentration (17.5%) for the group of women (n = 9), while in men, practically no changes were recorded. This suggests that training induced significantly greater changes regarding the concentration of this hormone in women, although it should also be noted that the baseline level of exercise capacity was slightly greater in men, which could potentially be of significance for the obtained results.

As it turns out, the reduction in leptin concentration also occurred after a vigorous period of strength training [43], which was implemented by rowers during the preparatory period, which further suggests that it is not the type of training loads used, but the total energy expenditure that is more important for the changes in this hormone during training. Interestingly, the introduction of 1-week recovery period after increasing training loads does not allow the leptin concentration to return to pre-training values. Considering the role of leptin in the control of food intake and the energy balance of the system, it could be concluded that the rowers examined in this study did not compensate for the disturbances in the energy status during the week devoted to regeneration. In this study, however, no reduction in body mass, adipose tissue or BMI was found, even after the hardest period of training, while the authors suggested that other factors, e.g. hormonal, may affect changes in leptin concentration after training.

One of the hormones that may be of importance here is cortisol, the decrease of which corresponded to a decreased level of leptin. Based on these results and the finding of reduced exercise capacity, the authors of this study indicated that the athletes may be in the early phase of OTS (overtraining syndrome). This condition may be characterised by a lowered cortisol concentration, which, as the authors point out, may contribute to the reduction of leptin levels [43]. Although it has not been proved in all studies that overtraining is associated with a decrease in cortisol concentration [44], the latest results provided by Grandys et al. [45] indicate that a decreased concentration of cortisol during physical training may be an early signal of overtraining development.

In the work by Simsch et al. [43], the first experimental data have been provided, in which leptin was proposed as a potential marker of training loads in rowing. In another study by Estonian scientists [3], a very similar experiment was carried out to that presented in the work by Simsch et al., also studying high-class rowers as the test subjects. During the 3-week period of significant increase in training loads, a significant decrease in the level of leptin (by 25%) was found, and after the next 2, when
the loads were reduced by 50%, an increase was found, although the concentration was still lower compared to the pre-training period. In this study, a decrease in insulin concentration by up to 25% from the baseline level was also observed. Therefore, it was confirmed that insulin may play an important role in the secretion of leptin.

In yet another study from the same year the possibility of using leptin was also confirmed as a marker of training loads in rowing training [4]. In this paper, it was shown that significant changes in leptin levels (in response to changing training loads) occur in the situation of slight, simultaneous changes in testosterone levels and no changes in cortisol levels. The authors concluded that the level of leptin may be a more sensitive marker of training loads compared to other hormones used to monitor training loads among athletes. Moreover, in research on the same group, it was found that post-training changes in exercise leptin secretion may also be an indicator of high training loads [42]. In this study, it was found that not only resting leptin levels are lowered after a period of hard training, but also its exercise release is reduced.

A team of Estonian scientists also undertook assessment regarding the long-term impact of rowing training [46]. Over a period of 24 weeks, 11 candidates for the Estonian national team participated in the research. Performance measurements carried out in rowing-specific tests (2-km race on water), during which the race time and the maximum VO2max at the beginning and at the end of the 6-month period, allowed for the inclusion of 6 rowers in the national team, while 5 competitors were rejected. Interestingly, in the group of the qualified competitors, the resting concentration of leptin at the end of the study was lower, and in the group of unqualified competitors, it was higher than the resting concentration at the beginning of the 6-month preparation period. In the group of selected athletes, a significant decrease in the content of adipose tissue was observed, while in the rest of the group, there were no differences in this indicator.

Conclusions

Based on the cited data, it may be concluded that leptin can be successfully used in many disciplines, particularly – in rowing – as a marker of training loads. Due to the high energy expenditure in rowing, leptin more frequently demonstrates changes in concentration in relation to both a single effort and entire training cycles. After analysing the literature, it seems that in order for the leptin concentration to decrease, the amount of energy expenditure in a single training unit must be higher than 800 kcal.

References:


The Role of Leptin in Monitoring...


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