Original Article

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Effect of bench press at a specified movement tempo on post-exercise testosterone and cortisol levels

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Abstract

Body response is a key element of the periodization of any training unit. The main control systems in the human body are the nervous and endocrine systems. The study aims to examine the effect of bench press at a specified movement tempo on post-exercise blood testosterone and cortisol levels. The study involved 16 men (experience in resistance training 5.5 ± 1.3 years, aged 24 ± 2 years, body weight 86.1 ± 7.2 kg, and 1RM 125 ± 17 kg). The first stage of the test focused on determining the maximum force based on a single bench press with the highest possible external load (1RM). The second stage included the main test, i.e. bench press. The participants were asked to perform 5 sets successively, with an external load of 70% of an individual 1RM and as many repetitions as possible. The tempo of the exercise was precisely specified. The metronome was used to set a bench press tempo. The movement tempo included time under tension (TUT) 2/0/2/0. TUT means the total time of muscle tension during one repetition. The tests showed significant changes in cortisol levels recorded 30 minutes after exercise, amounting to 13.75 (±4.60) at F=9.16 and p=0.006. and 60 minutes after exercise, amounting to 11.37 (±4.17) at F=19.46 and p=0.0002. No significant statistical values were found for testosterone levels. This study brings additional evidence of the importance of hormonal responses in muscle strength training.

Keywords: testosterone, cortisol, movement tempo, bench press

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INTRODUCTION

Exercise intensity is one of the key variables in sports training and has a significant impact on training adaptations. In resistance training, exercise intensity is usually evaluated based on a maximum weight lifted during one repetition (one-repetition maximum, RM). Furthermore, 1RM is considered to be an effective method for the measurement of muscle strength in non-laboratory settings [1]. Although 1RM is commonly used in resistance training, previous testing procedures for evaluating 1RM in a standardized manner failed to provide detailed guidelines related to movement tempo or duration of the individual phases of an exercise (eccentric-concentric) [2], which may be problematic in terms of using different tempos in training periodization. Movement tempo is often defined as tempo, cadence, or lifting speed during a resistance exercise [3]. Therefore, tempo is usually described using a sequence of digits (e.g. 2/0/3/0), with each digit indicating the duration (in seconds) of a specific phase of the motion (eccentric/isometric/concentric/isometric), while "V" is used to indicate that the phase should be performed at a variable tempo and "X" to indicate a phase that is performed explosively or as fast as possible.

Body response is a key element of the periodization of any training unit. The main control systems in the human body are the nervous and endocrine systems, which can be used to monitor external and internal changes [4]. Homoeostasis is controlled by the endocrine system acting in response to specific phenomena, mostly drastic and sudden [5]. The work done by the body is inseparably related to the stress stimulus acting on the endocrine system, which is reflected by post-exercise adaptations. This shows the importance of proper stimulation of the endocrine system. These relationships also emphasize the significance of post-exercise recovery [6]. Anomalies of catabolic or anabolic processes are closely related to the amounts of adequate hormones and growth factors (IGF-I). Acid-base balance, metabolism, and development and growth of the body depend on the efficiency of hormonal processes. In addition to the resynthesis of damaged muscle cells, other functions of hormones include performing the role of physiological markers determining anabolic body potential [7], indicating the dominance of catabolic processes, which sometimes provides arguments for overtraining [8].

Many studies have examined the effect of exercise related to resistance training and its effect on the levels of individual hormones. In many cases, it is impossible to identify the main factor responsible for the growth or decrease in blood levels of a hormone or another marker. Although a number of studies have been conducted on the post-exercise responses of the endocrine system, the results are still inconclusive. Therefore, further analysis is needed to explore these phenomena. Only studies that evaluate changes in several parameters simultaneously can provide reliable information about the effects of specific physical exercise on the endocrine system [9]. There are many relationships between the effects of individual hormones. Some of them act synergistically on each other, whereas others act antagonistically [10]. High plasma insulin levels limit the secretion of growth hormone, and there is a correlation between testosterone and cortisol levels, with high insulin levels stimulating testosterone secretion [11]. Furthermore, in addition to training-related factors, the type of diet and supplementation used also have a significant effect on hormone levels. Changes in testosterone levels depend on dietary factors [12,13].

Sports training consists in using variable stimuli to initially induce the prevalence of catabolic reactions. The first stage of training adaptations is muscle catabolism, which persists during training and, depending on the type of physical activity, from a few to several hours following the training session. Physical exercise causes stress, which is related to the catabolic state of the body. Two major biological systems are involved in the stress response: the sympathetic system and the hypothalamic-pituitary-adrenal axis (HPA). The sympathetic nervous system is activated at the beginning from the stimulus i.e. physical exercise in this case. This system simulates adrenals for adrenaline and noradrenaline secretion. Next, the HPA axis is activated because several minutes or hours following the stress stimulus, the hypothalamus secretes corticotropin-releasing hormone (CRH), which stimulates the pituitary gland to secrete adrenocorticotropic hormone (ACTH). It stimulates the adrenal cortex to secrete corticosteroids, with cortisol released in the greatest quantities. The activity of the HPA axis is based on negative feedback and then corticosteroids inhibit pituitary and hypothalamic activity. Physical exercise is an important factor causing stress and a potential activator of the HPA axis [14]. Of all corticosteroids, cortisol accounts for 95%. It was found that an increase in cortisol levels can occur not only during physical exercise but also while waiting for sports competition [15]. Its post-exercise changes are influenced by the resting levels of the hormone [16]. Cortisol is a catabolic hormone and is responsible for muscle protein degradation and performs many functions in the body. With regard to fast-twitch type II fibres, the catabolic effect of cortisol is much greater [17]. Therefore, its importance and role is critical to glycolytic exercise. Increased release of fatty acids and amino acids into the bloodstream is connected with cortisol-stimulated lipolysis in adipose tissue and inhibition of protein synthesis in muscle tissue. Cortisol has many physiological functions, including maintaining a sodium balance, regulating blood pressure, and maintaining glycolytic homeostasis [18].

MATERIAL AND METHODS

The study involved 16 men with 5.5 ± 1.3 years of experience in resistance training. The age of the study participants was 24 ± 4 years, body weight was 86.1 ± 7.2 kg, and 1RM= 125 ± 17 kg. The testing protocol and the written consent of the participants were in accordance with the ethical standards of the Declaration of Helsinki. The participants followed a similar dietary plan within seven days before the tests. They were instructed not to use any dietary supplements nor stimulants.

Before the measurements, the participants performed a ten-minute warm-up on the Keiser ergometer (M3 Total Body Trainer) (heart rate ca. 135 bpm for 5 minutes). Next, 10 body pull-ups from hanging position on the bar and 15 push-ups were performed. The final part of the warm-up was 3 sets of bench press at tempo 2/0/2/0: 20 kg - 15 repetitions, 40% 1RM - 10 repetitions, 60% 1RM - 5 repetitions. After the warm-up, the participants began the main part of the experiment, i.e. 5 sets of bench press with 70% 1RM at 2/0/2/0 tempo. The tempo was set by the metronome and every attempt was performed to exhaustion. The rest between sets was 3 minutes. During the sets, the subjects were motivated to perform the maximum exercise [19].

The first stage of the test focused on determining the maximum force based on a single bench press with the highest possible external load (1RM). Ten bench press repetitions with relatively low external load were performed first in order to determine 1RM. In subsequent sets, the external load was increased according to the decision of the participant. The load increase ranged from 1 to 20 kg. 1RM was achieved in 3 to 6 sets. The break between the sets was 60 seconds [1] This allowed for the evaluation of the individual on-repetition maximum weight for each participant. The participants were requested to refrain from any resistance training at least 72 hours before the next stage of the tests, which were planned to take place a week after the first stage. The second stage included the main test, i.e. bench press. The participants were asked to perform 5 sets successively, with an external load of 70% of an individual 1RM and as many repetitions as possible. The tempo of the exercise was precisely specified. The metronome was used to set a bench press tempo. The movement tempo included time under tension (TUT) 2/0/2/0. TUT means the total time of muscle tension during one repetition. The interval between consecutive sets was 3 minutes [20]. After the athlete stopped the movement, the test was interrupted and the number of repetitions and duration of the set were recorded. Before the exercise, each participant performed a standardized warm-up. The training was conducted according to the planned schedule (Table 1).

During the experiment, venous blood samples were obtained from the basilic vein (10ml) in order to evaluate resting and post-exercise biochemical levels of the variables studied. Samples where send to external lab. Blood samples were taken at the following moments: rest, immediately after the exercise, 30 minutes after the exercise, 60 minutes after the exercise.

Table 1. Test design.

Warm – up					Test			
Sets	Reps	Weight	Tempo	Rest [min]	Sets	Reps	Weight	Tempo
1	6	20 kg	2/0/2/0	1	5	max	70 % 1RM	2/0/2/0
1	6	40 % 1RM	2/0/2/0	2				
1	6	60 % 1RM	2/0/2/0	2				

Statistical analysis

A one-way analysis of variance was employed to determine the significance of differences for means. The null hypothesis was that the means of the variables studied do not differ significantly from each other. An alternative hypothesis marked H1 was also formulated: there are significant differences between at least two series of measurements (there are significant differences between the means of the variables studied). The level of significance was set at α=0.05. The analysis of variance does not indicate the groups with significant differences between each other and therefore, during further research, we used Tuckey's multiple comparison post-hoc tests.

RESULTS

Figure 1 presents the regularly decreasing mean duration of the longest possible exercise performed by the participants. Figure 2 shows a mean number of repetitions declining with consecutive sets. Table 2 contains the measurements of the analysed blood hormone levels. The mean baseline testosterone levels were 516.22 (±145.57) ng/dl, whereas immediately after exercise, they were 588.50 (±161.76) ng/dl. Regarding cortisol, the baseline was 19.64 (±5.64) µg/dl, whereas after the experiment, its levels were 17.50 (±5.49) µg/dl. However, these variables did not show any statistical significance. Table 2 contains the measurements of the analysed blood hormone levels. The mean baseline testosterone levels were 516.22 (±145.57) ng/dl, whereas immediately after exercise, they were 588.50 (±161.76) ng/dl. Regarding cortisol, the baseline was 19.64 (±5.64) µg/dl, whereas after the experiment, its levels were 17.50 (±5.49). However, these variables did not show any statistical significance. The values occurring consecutively 30 minutes after exercise - testosterone levels were 549.31 (±157.87) ng/dl, whereas cortisol levels were 13.75 (±4.60) µg/dl, which was statistically significant at F=9.16 and p=0.006. Consecutive statistically significant changes in cortisol levels recorded 60 minutes after exercise, amounting to 11.37 (±4.17) µg/dl at F=19.46 and p=0.0002. No significant statistical values were found for testosterone levels, which were 556.69 (±148.56) ng/dl. The variables concerning the relationships between blood obtained immediately after exercise and 30 minutes after exercise - only the variable of cortisol levels proved to be statistically significant at F=3.83 and p=0.06. No statistical significance was demonstrated for testosterone. Obtained statistical significance of blood cortisol levels between the period immediately after and 1 hour after the test, with F=11.07, p=0.003. No statistical significance was demonstrated for testosterone.

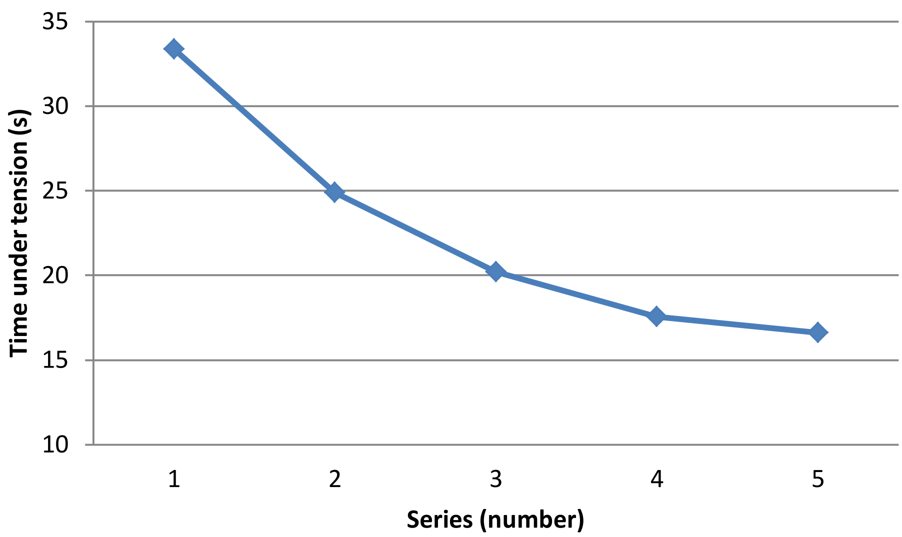

Figure 1. Results of the analysis of changes in the time to reach muscular failure in each of the five sets.

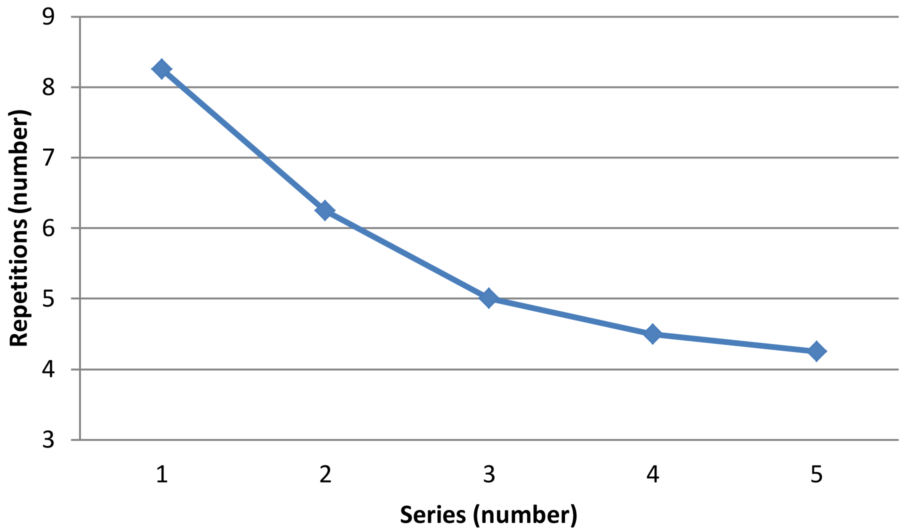

Figure 2. Results of the changes in the maximal number of repetitions for each of the five sets.

Table 2. Hormone levels and hormone level differences between obtained blood samples.

Morphological parameters	Mean (±SD)		ANOVA	
	Before the test	After the test	F	p
Testosterone	516.22 (±145.57)	588.50 (±161.76)	1.54	0.23
Cortisol	19.64 (±5.64)	17.50 (±5.49)	1.03	0.32
	Before the test	30 min after the test		
Testosterone	516.22 (±145.57)	549.31 (±157.87)	0.33	0.57
Cortisol	19.64 (±5.64)	13.75 (±4.60)	**9.16**	**0.006**
	Before the test	1h after the test		
Testosterone	516.22 (±145.57)	556.69 (±148.56)	0.53	0.47
Cortisol	19.64 (±5.64)	11.37 (±4.17)	**19.46**	**0.002**
	After the test	30 min after the test		
Testosterone	588.50 (±161.76)	549.31 (±157.87)	0.42	0.52
Cortisol	17.50 (±5.49)	13.75 (±4.60)	**3.83**	**0.061**
	After the test	1h after the test		
Testosterone	588.50 (±161.76)	556.69 (±148.56)	0.29	0.59
Cortisol	17.50 (±5.49)	11.37 (±4.17)	**11.07**	**0.003**

DISCUSSION

Based on the analysis of the results concerning the response of the endocrine system, it seems justified to conclude that the TUT 2/0/2/0 induces the desired responses of some key anabolic hormones [21]. Interventions in training intensity and training volume bring beneficial responses of the endocrine system [22]. No major hormonal changes were observed by Headley in his 2011 study that compared exercise performed at tempos 4/0/2/0 and 2/0/2/0 [23]. As can be seen, the compared tempos are quite similar. The conditions in which the tests were conducted did not deviate significantly from the standard, i.e. the required tempo 2/0/2/0 was quite close to the basic volitional tempo. This leads to the conclusion that if tempos with more distant values were compared, especially in the negative phase of the movement, the monitored variables would reflect clearer differences. The likely outcome would lead to positive findings concerning key anabolic hormones.

The results obtained in the tests did not show statistically significant post-exercise changes in blood testosterone levels. These findings are consistent with the research carried out by West [24], which showed that exercises involving small muscle areas do not induce a beneficial post-exercise increase in testosterone levels. Furthermore, the test results may be related to the age of the participants and their high resting testosterone levels [25]. Although adequate training conditions, external load values, training volume, and rest duration were used, no significant post-exercise changes in testosterone levels were observed. This may indicate that optimal parameters cannot be considered independently, but all parameters must be met in order to achieve the desired increase in testosterone levels.

Changes in testosterone levels that occur during resistance training do not only depend on the training load, but also on the muscle area involved in the exercise [26], and the type of diet and supplementation [27]. Another factor is the age of the athletes and their training experience [28]. The mean age of participants was 24 years, which is related to the high resting testosterone levels of 516.22 (±145.57) ng/dl. The high initial state limits a further increase in this hormone, and the exercise performed will not exceed its natural norm. An additional element that increased the high resting testosterone levels in study participants was the time of the day during the tests (before noon). In the circadian rhythm, testosterone is synthesized in an amount of ca. 6 mg per day. The highest production is observed in the morning whereas the lowest - in the afternoon. Normal levels of this hormone in healthy men range from 2.3-3.5 ng/ml (8-12 nmol/l) [29]. No significant changes in post-exercise testosterone levels were recorded if its resting levels were low [30]. The results obtained for weightlifters did not show any changes in testosterone levels following a training session performed in the morning. A similar situation was recorded in the present study. Such a reaction results from the human biological rhythm. When training in the morning, the increase in testosterone levels disappears due to naturally significant levels. Other destabilizing factors include additional stress, ambient temperature, and even sleep depth, sexual activity, and many external factors, which may also have caused statistically insignificant changes in testosterone levels observed in the study. Research has shown that the level of muscle fatigue is related to the post-exercise increase in testosterone levels. If weightlifting exercises are used, the increase in plasma testosterone levels is the highest due to the fact that large numbers of muscle groups are involved simultaneously [21,22,31]. The research concerned the bench press, i.e. exercise involving a relatively smaller area of muscles compared to squats, which could have had a significant effect on the small increase in testosterone levels after exercise. However, it should be noted that there has been a tendency for testosterone to increase during exercise and decrease immediately after exercise. However, from the thirtieth minute after exercise, the hormone levels were reported to increase again and it should be emphasized that this indicates the initial moment of testosterone recovery. Increasing muscle exhaustion has an effect on changes in testosterone levels [32]. The authors demonstrated a relationship between increased testosterone and blood lactate levels. The elevated testosterone levels are associated with elevated lactate and catecholamine. Increased lactate stimulates the production of cAMP (3',5'-cyclic adenosine monophosphate) and testosterone synthesis in Leydig cells [33] Another study demonstrated that long-term muscle strength training can lead to an increase or decrease in the secretion of individual hormones in the circadian cycle and their resting levels [31]. The tests caused muscle failure as the exercise was performed by participants until volitional exhaustion, which confirms that the procedure could induce an increase in testosterone levels. The value of the external load applied during the tests was 70% 1RM, as reported by Ratamess [34], who demonstrated that the external load value of 70-80% 1RM and the mean exercise volume is a stimulus for a post-exercise increase in testosterone levels. Although these training parameters were employed in the present study, training components that interfere with increased testosterone levels (e.g. rest duration) were also used. The lack of identification of the most accurate external load value can also be emphasized [35,36]. The optimal value of external load stimulating the post-exercise increase in testosterone levels should be 85-90% 1RM, as demonstrated in a number of studies [37]. The rest duration between sets is one of the factors that translates, due to the effect of training exercise, into the increase in testosterone levels. The optimum rest between sets must not exceed 60 seconds [20,36]. In the present experiment, the rest between the sets was 180 seconds. Therefore, the lack of desired responses from the endocrine system can also be expected in this case as the rest duration turned out to be too long. An important training parameter that triggers changes in testosterone levels is optimal intervals between sets.

In the case of cortisol hormone, statistically significant changes in the recovery period were clearly observed for 30 minutes and 60 minutes from the completion of the exercise. The blood levels of this hormone declined with each measurement. Since the measurement at rest, statistically significant reductions in cortisol levels immediately after exercise, 30 minutes after exercise and one hour after exercise were recorded. The only statistically insignificant value was that obtained immediately after exercise compared to the resting value. Cortisol is a hormone of catabolic nature that plays a significant role in the human body. Firstly, it is critical to the process of energy acquisition, and secondly, it is described as a real indicator of the physical fatigue of an athlete. The catabolic state induced during training and the time of its prevalence in the body depend on the training load applied during the training session and the sports skill level of the individual. Resistance training leads to post-exercise changes not only in hormones with anabolic functions, but also those of the catabolic nature. As one of the most important markers of the catabolic state, cortisol is sensitive not only to exercise, but also to such factors as the time of the day when the training is performed, the muscle area used in the training, the diet used, the age of the individual, and training experience. The highest cortisol levels are most often observed in the morning and decline during the rest of the day, and the lowest level is reached at around midnight. The research conducted shows that limiting the nocturnal increase in cortisol levels can theoretically be achieved by using adequate supplementation [38]. A training session performed before noon is associated with higher resting cortisol levels, as was the case in the present study. Similar to testosterone changes, this phenomenon is referred to as a human biological rhythm [39]. The level of resting cortisol can increase during a training session. There are studies demonstrating the relationships where the resting value of cortisol levels is high, and no increase in this hormone is recorded after the training session [40]. Scientific research shows that cortisol is a significant catabolic indicator only if the muscle effort occurs for more than ten seconds [41]. This fact confirms the validity of the physical exercise chosen in the present study, with the muscle time under tension ranging from 34 seconds (the first set) to 17 seconds (the fifth set). On the other hand, the exercise volume was at an average level whereas rest duration was relatively long, which disturbed the increase in this hormone. There are speculations that there is a level of fatigue or muscle exhaustion above which an increase in cortisol levels is observed. However, this has not been clearly demonstrated to date. Continued research showed that, although the maximum possible number of sets was used, a 5-minute rest between sets did not cause significant glycolytic disturbances and did not lead to the desired increase in cortisol levels. A significant increase in cortisol secretion is observed when the muscles are extremely fatigued, which in turn, due to exercise intensity, is associated with increasing exhaustion of the nervous system and depletion of phosphagen energy sources. The human body exposed to the load that forces exercise in the phosphagen zone does not cause an increase in cortisol levels. The presented results disprove the validity of considering this hormone as a parameter of catabolic changes in the body among individuals who attempt to develop maximum muscle strength. The measure of the work done can be the resting blood cortisol levels, while muscle strength training does not determine the continuous activation of cortisol in response to exercise [37,39,41].

In conclusion, it should be emphasized that for beneficial changes in a hormone to occur, all the requirements of each training element must be met as a whole and inseparably. In the absence of insufficient meeting the requirements for one element, the whole process is disrupted and the desired results cannot be achieved. The attempts to find answers to the research questions asked in this study lead to unequivocal and firm conclusions. Bench press at a tempo 2/0/2/0 does not affect significant post-exercise changes in testosterone levels. Bench press at a tempo 2/0/2/0 leads to significant post-exercise changes in cortisol levels.

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