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# Selected kinematics characteristic during bench press by disabled powerlifting athletes

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## Abstract

**Background & Study Aim:** The main criterion of extreme weightlifting is body burden with high level of effort. The aim of the study was knowledge about effect of the weight of the barbell on the behavior of some kinematic parameters recorded during the bench press by disabled powerlifters.

**Material & Methods:** Twenty-nine disabled weightlifters (23.9±6.1 years) from Disabled Sport Association were examined. Each subject performed a bench press, respecting all rules and regulations, 4 times. The subjects lay supine on the powerlifting bench, afterwards they took the bar from the racks, lowered it down to the chest and pressed upwards till full extension of the elbows. Following loads were used: 40% 1RM, 60% 1RM, 80% 1RM and 95% 1RM (1RM–one repetition maximum). A potentiometer was used to register time of movement and distance. Empiric distribution of analyzed characteristics did not differ from normal distribution, what was evaluated with the Shapiro-Wilk test. Distribution comparison at different loads analysis were calculated with the t-test for dependent samples ($p<0,05$). Spearman's rank correlation coefficient for parameters in upwards and downwards movement was calculated.

**Results:** Time, velocity and acceleration of downward movement towards the chest were similar for all loads in all examined athletes. During upward movement the time increased from the load 60% 1RM or more, whereas velocity and acceleration decreased with the bar load increase. Velocities were correlated in upward and downward movement, which means that the faster the athletes lowered the bar, the faster they also pressed it up. In 95% 1RM trial the maximal acceleration did not differ statistically significant. Correlations between maximal acceleration in upward and downward movement were significant up to 80% 1RM.

**Conclusions:** Bar load increase did not cause significant changes of kinematic parameters during downward movements, during upward movement the bar load influenced the parameters' changes significantly. The time of movement increased, while velocity and acceleration values decreased.

**Key words:** kinematic parameters, muscle strength, sports, upper extremity, weight lifting

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**Extreme sport** – "extreme form of physical activity are extreme sports, often classified according to the environment in which they are performed (water, land, air), extreme form of physical recreation as well as gainful activity or voluntary service, and all varieties of physical activity that meet at least one classification criterion of the feature associated either with extreme risk of injury or death, or extreme body burden with high level of effort, or extreme coordination difficulty" [18, p. 19].

## INTRODUCTION

Disabled powerlifting is a Paralympics discipline basing mainly on weight training. Its advantage is an increase in strength and muscle mass [1-2]. In this discipline a competitor while laying supine on a heavy-weight bench takes the bar from the rack and, by bending upper limbs, lowers it down to the chest and next presses it upwards, till full extension of the elbows. Thus it can be stated that this movement consists of bending and straightening of the upper limbs and it is performed in two joints – glenohumeral and elbow, and its features define the technique of the exercise.

While performing a lift, a competitor must generate strength both while bending (bar lowering) and while straightening upper limbs (bar pressing) so that they can overcome or counteract bar weight. Downward bar movement requires muscle activation in an eccentric way, while upward one – concentric. Therefore, it is necessary to first generate strength in an eccentric way and then in a concentric way. Generating strength with upper limbs at right time can be perceived as a crucial factor when trying to avoid premature tiredness or injury caused by too heavy load [3].

Scientific literature lacks unambiguous conclusions in terms of changes in the kinematic parameters with an increase in the barbell weight. Newton et al. [4] observed significant acceleration at the beginning of the concentric phase while pressing with high velocity and relatively low weight of the bar. In the final phase of pressing occurred a decrease of speed, which was accompanied by reduction of agonistic electromyography activity. In consequence, large forces were generated only in a small movement range.

It can be assumed that the success in disabled weightlifting as well as improvement of their functional state depends not only on generation of muscle power [5]. Garhamer stated that achieving good results by both experienced and inexperienced weightlifters was not only dependent on the amount of generated strength, but also on the ability to generate maximum strength at the right moment [6]. In accordance with strength-speed dependence it can be predicted that with larger bar weight the movement will be slower.

Examining the variability of basic kinematic parameters of the lift depending on barbell weight in disabled weightlifters may give answers to whether their qualities can be established and specified, so that the movement structure will allow for optimal use of strength capabilities. Answering this could contribute to increase the level of the sport, lower the risk of injury, improve functioning of the disabled, as well as enable to raise some cognitive conclusions.

The aim of the study was the knowledge about the effect of the weight of the barbell on the behavior of some kinematic parameters recorded during the bench press by disabled powerlifters. This analysis will allow to better understanding the influence of barbell's weight on its movement and therefore will provide trainers and competitors with practical instructions on correct load selection, depending on the assumed goal while training disabled powerlifters.

## MATERIAL AND METHODS

Twenty-nine skilled disabled weightlifters were covered by the study. Participants were 23.9±6.1 years old, and their training experience was 5.4±3.6 years. All weightlifters showed normal performance of upper limbs. The level of participants was very high – each was Polish Championships or higher ranked event medalist. While being examined, all participants were at the sub period of preparation for special annual training cycle.

The experiment was based on a disabled competitor performing the lift according to all regulations in the discipline. The lift was performed with subjects lying supine on the powerlifting bench, taking the bar from the racks, lowering it down to the chest and pressing it upwards till full extension of the elbows. The lift was done on a standard – attested equipment used during high ranked sport events.

Before the experiment, the disabled weightlifters did standard warm-up (precisely defined by the trainer), and afterwards, in conditions similar to those of sporting competitions, they began pressing the barbell weighting: 40% 1RM, 60% 1RM, 80% 1RM and 95% 1RM. Maximum weight, which an athlete is able to press only once (1RM) was set for each subject the day before. Setting maximum weight possible to lift just once (1RM) has been done according to the established procedure [7,8].

A competitor laying supine on the powerlifting bench gripped the bar. The barbell was placed on racks with height adjusted to the hands spacing of the competitor. The spacing of the hands was determined by arrangement of upper limbs. Weightlifter arms remained in abduction at a 90˚ angle and forearms flexed at a right angle in relation to the arms. In this position grip width was marked on the barbell, which could not be changed in the following attempts. Indicated grip width was used in the experiment, as it causes balanced involvement of muscles, while such grip is considered to be the most effective during the lift [9].

To measure the movement of the bar a potentiometric sensor was used, which registered duration of the motion and distance. The sensor was mounted at a height of 1.2 m, on a special tripod standing at a distance of 2 meters from the center of the bar. The sensor was mounted rigidly on a standing frame, and elastic cord (determining the change in the position of the bar) was connected directly to the center of the bar. The cord remained slightly tense throughout the study to eliminate the horizontal movement of the bar. When the position of the bar changed, the angle α underwent a change. Recording changes of the angle as a function of time was used to calculate the path of the barbell and then the speed and acceleration. The maximum speed of the bar (Vmax) denoting the highest value of the instantaneous speed was calculated from the first derivative of distance to time. The maximum acceleration of the bar (Amax), for which the highest value of the instantaneous speed of the second derivative of distance to time was adopted, was also calculated. All parameters were calculated during upwards and downwards movements of the barbell. It should be emphasized that for a maximum acceleration value during the downward movement maximum value of the deceleration was assumed, that is while braking before touching the bar to the chest. During the upward movement for maximum acceleration value the highest value during barbell acceleration was adopted. Next, it was determined whether differences in the duration of the lift, the duration of barbell lowering phase, the duration of the extrusion phase, maximum speed and maximum acceleration at each barbell weights are statistically significant. In addition, it was found that the value of each parameter, with the same barbell weight, differ during the upwards and downwards movements. The relationships that occurred between each parameter of the upwards and downward movements were also established.

Empirical distributions of analyzed traits did not differ significantly from the normal distribution, as determined using the Shapiro-Wilk test. Comparison of distributions with different barbell weights were performed using t-Student test for dependent attempts. All statistical inference were estimated at a significance level of $p < 0.05$. Measured parameters of upward and downward movement were the correlated using Spearman's rank correlation coefficient.

## RESULTS

### Analysis of the duration of the press

The increase in barbell weight did not affect the duration of the downward movement. When moving the barbell upward, along with increasing weight, tendency to increase the average value of its duration could be observed.

**Table1.** Assessment of the significance of differences in movement durations in successive pairs of barbell weights.

| Barbell movement | Weights compared | Mean Difference [s] | Student test | |
|---|---|---|---|---|
| | | | t | p |
| downward | 40% - 60% | 0.020 | 0.302 | 0.765 |
| | 60% - 80% | 0.005 | 0.105 | 0.917 |
| | 80% - 95% | −0.036 | −0.657 | 0.516 |
| upward | 40% - 60% | 0.04 | 0.99 | 0.329 |
| | 60% - 80% | 0.24 | 4.87 | **<0.001** |
| | 80% - 95% | 0.55 | 6.92 | **<0.001** |

*significance level $p<0.05$

As can be seen from the results listed in Table 1, extending the average duration of the extrusion phase was not linear. The difference in upward barbell movement times with weights up to 40% 1RM and 60% 1RM was not significant, only extending the weights over 60% of 1RM was statistically significant. In view of the almost invariable average duration of barbell lowering phase, regardless of its weight, the corresponding significance of medial differences were observed when considering the duration of the entire press. It can therefore be assumed that the extension of the duration of the entire lift was dependent on changes in length of the barbell pressing phase, with an increasing weight of the barbell. Average upward movement time was shorter with barbell weight not exceeding 80% of 1RM, and longer with a weight of 95% 1RM. With the increase in the weight of the barbell differences between the duration of the upward and downward movements declined, while they remained statistically significant regardless of the weight of the barbell (Table 2).

**Table 2.** Comparison of the duration of the upward and downward barbell movements in the individual weights of the barbell.

| Barbell weight | Barbell movement | Movement duration [s] | | Student test | |
|---|---|---|---|---|---|
| | | Mean | Standard deviation | t | p |
| 40% | downward | 1.479 | 0.442 | 7.081 | **<0.001** |
| | upward | 0.928 | 0.243 | | |
| 60% | downward | 1.459 | 0.411 | 6.542 | **<0.001** |
| | upward | 0.967 | 0.267 | | |
| 80% | downward | 1.454 | 0.428 | 2.867 | **0.008** |
| | upward | 1.210 | 0.323 | | |
| 95% | downward | 1.490 | 0.373 | 2.384 | **0.02** |
| | upward | 1.759 | 0.559 | | |

*significance level $p<0.05$

In order to clarify the relations that occurred between the duration of the upward and downward movements, the correlation coefficient r-Spearman was calculated. Determining the relationship between the duration of upward and downward movements with individual barbell weights allowed to give answer to the question whether the duration of the upward movement could depend on the duration of the downward one? If this relation occurred, did it affect all barbell weights or only some of them?

With the increase in the barbell weight, the value of correlation coefficient decreased (Table 3). This suggests that the bar pressing time was less and less dependent on the duration of its lowering with the increase of its weight. The durations of the upward and downward barbell movements were significantly correlated only with the barbell weight of 40% 1RM. This meant that the longer the competitors lowered the barbell, the longer lasted the upward movement.

**Table 3.** Summary of correlation coefficients between the duration of upward and downward movement for individual barbell weights.

| Barbell weight | r |
|---|---|
| 40% 1RM | **0.403** |
| 60% 1RM | 0.359 |
| 80% 1RM | 0.327 |
| 95% 1RM | 0.230 |

### Analysis of the maximum speed

The maximum speed in downward movement remained almost unchanged for all barbell weights. However, in upward barbell movement maximum speed of the bar significantly decreased with the increase of its weight (using 40% 1RM weight of the barbell maximum speed was approximately 1.4 m/s, while at the highest load it was more than halved). Observed differences in maximum speed in upward movement were statistically significant (Table 4).

**Table 4.** Comparison of the maximum speed values of the downward and upward movements in the individual weights of the barbell.

| Barbell movement | Compared weights | Mean Difference [m/s] | Student test | |
|---|---|---|---|---|
| | | | t | p |
| downward | 40% - 60% | 0.101 | 0.593 | 0.558 |
| | 60% - 80% | −0.057 | 0.808 | 0.426 |
| | 80% - 95% | 0.084 | 1.416 | 0.168 |
| upward | 40% - 60% | 0.258 | 3.459 | **0.002** |
| | 60% - 80% | 0.185 | 3.226 | **0.003** |
| | 80% - 95% | 0.327 | 4.666 | **0.001** |

*significance level p<0,05

The value of the maximum speed in upward barbell movement was significantly higher than the maximum speed in downward movement at loads of 40% 1RM and 60% 1RM, similar with a load of 80% of 1RM, and significantly lower at 95% 1RM load (Table5 ).

**Table 5.** Comparison of the maximum speed of the downward and upward movements for different barbell weight.

| Barbell weight | Barbell movement | Vmax [m/s] | | Student test | |
|---|---|---|---|---|---|
| | | Mean | Standard deviation | t | p |
| 40% | downward | 0.90 | 0.73 | 4.57 | **0.0001** |
| | upward | 1.41 | 1.26 | | |
| 60% | downward | 0.80 | 0.56 | 4.44 | **0.0001** |
| | upward | 1.15 | 0.91 | | |
| 80% | downward | 0.86 | 0.70 | 1.86 | 0.0629 |
| | upward | 0.96 | 0.90 | | |
| 95% | downward | 0.78 | 0.62 | 3.21 | **0.0013** |
| | upward | 0.63 | 0.59 | | |

*significance level p<0.05

The correlation coefficients between the maximum speed of the downward barbell movement and a maximum speed of the upward one at individual barbell weights were statistically significant. The strongest correlation between the velocities was observed at the maximum weight of the barbell at 60% 1RM, and the weakest at 40% 1RM (Table 6).

**Table 6.** Summary of correlation coefficients between the maximum speeds in the downward and upward barbell movements for different barbell weight.

| Barbell weight | r |
|---|---|
| 40% 1RM | **0.542** |
| 60% 1RM | **0.654** |
| 80% 1RM | **0.571** |
| 95% 1RM | **0.550** |

### Analysis of maximum acceleration

Maximum acceleration value (Table 8) in the downward barbell movement was very similar in all barbell weights. In upward barbell movement the maximum acceleration value decreased linearly with the increase of the barbell weight. Reducing the value of the maximum acceleration in the upward barbell movement was statistically significant in character with increasing barbell weight (Table 7).

Maximum acceleration in upward barbell movement was significantly higher than the maximum acceleration in downward barbell movement with barbell weights of 40% 1RM, 60% 1RM and 80% 1RM. With the barbell weight 95% 1RM maximum acceleration values were similar. The difference between the maximum acceleration value in upward and downward barbell movement decreased with increasing the barbell weight (Table 8).

**Table 7.** Comparison of the maximum acceleration in the downwards and upwards barbell movements for different barbell weight.

| Barbell movement | Compared weights | Mean Difference [m/s$^2$] | Student test | |
|---|---|---|---|---|
| | | | t | p |
| downward | 40% - 60% | 0.046 | 0.350 | 0.729 |
| | 60% - 80% | −0.533 | −0.965 | 0.343 |
| | 80% - 95% | 0.590 | 1.340 | 0.191 |
| upward | 40% - 60% | 1.604 | 4.081 | **0.001** |
| | 60% - 80% | 0.946 | 2.075 | **0.047** |
| | 80% - 95% | 1.505 | 3.208 | **0.003** |

*significance level p<0.05

**Table 8.** Comparison of the maximum acceleration in downward and upward barbell movements for different barbell weight.

| Barbell weight | Barbell movement | Amax [m/s²] | | Student test | |
|---|---|---|---|---|---|
| | | Mean | Standard deviation | t | p |
| 40% | downward | 2.92 | 1.93 | 4.70 | 0.0001 |
| | upward | 6.66 | 4.96 | | |
| 60% | downward | 2.88 | 1.95 | 4.42 | 0.0001 |
| | upward | 5.06 | 3.19 | | |
| 80% | downward | 3.41 | 3.65 | 2.95 | 0.003 |
| | upward | 4.11 | 3.50 | | |
| 95% | downward | 2.82 | 2.44 | 0.36 | 0.7213 |
| | upward | 2.61 | 2.04 | | |

*significance level $p<0.05$

Calculated values of correlation coefficients between the maximum acceleration in downward and upward barbell movements showed that the correlations were significant at the barbell weights from 40% 1RM to 80% 1RM. Particularly strong correlation of both values occurred at barbell weights of 40% 1RM and 60% 1RM. With the barbell weight of 95% 1RM, this correlation was the weakest and not statistically significant (Table 9).

**Table 9.** Summary of correlation coefficients values between the maximum acceleration in downward and upward barbell movements for different barbell weight.

| Barbell weight | r |
|---|---|
| 40% 1RM | **0.652** |
| 60% 1RM | **0.723** |
| 80% 1RM | **0.501** |
| 95% 1RM | 0.290 |

## DISCUSSION

The research problem of the study was to analyze selected kinematic parameters of weightlifting for disabled and an attempt to assess the impact of the different barbell weight on their values. Establishing such problem was due to the fact that the abnormal pattern of movement could cause inefficient performance of the lift, which resulted from the fact that the competitors were not able to fully utilize their potential strength [10].

Inaccurate or ineffective execution of movements could have also been an obstacle to the functioning of people with disabilities in everyday life. The research problem was solved by setting the duration of the movement, the maximum speed with which it was executed and instantaneous acceleration in the different phases of movement at different barbell weights. All analyses were performed using four barbell weights, i.e. 40%, 60%, 80% and 95% 1RM. Such loads were most often used in the training of disabled weightlifters.

This issue is particularly important in doing sport by people with disabilities, where it is an important factor of evaluation, shaping and improving sports technique. It seems therefore, that the analysis of the factors determining the correct completion of the movement, may affect the achieved result, given the fact that in this sport the athletic level significantly increased in recent years [11]. The results of these studies may help in developing a precise definition of reliable parameters (features) of performing the lift, knowledge of which determines conscious and effective management of the training process of a disabled athlete, which consequently may provide a higher athletic performance.

The results obtained seem to be quite interesting. This particularly related to the downward barbell movement (lowering it on the chest) where there were no registered changes to any of the analyzed parameters. However, during the upward barbell movement the parameters have changed. The nature of those changes was different. The duration of the upward barbell movement lengthened with increase in its weight, but this relation occurred only when the barbell weight exceeded 60% 1RM. The other analyzed parameters (maximum speed and maximum acceleration) decreased with increase of the barbell's weight.

Downward barbell movement consisted of its controlled lowering on the chest. It can therefore be said that the competitor inhibited the downwards barbell momentum caused by the force of gravity. Slower lowering of the barbell meant that the competitor had put more strength in the movement. It also proved that the movement was performed in a more controlled manner. Faster barbell lowering meant less controlled movement, which means the strength used to perform it was lower. Good control of this movement meant conscious and precise dosage of strength for the optimal solution to complete the motor task. If a competitor sufficiently controlled barbell movement, then it was possible to precisely steer it in accordance with their intention. It was also possible to accurately receive and correct mistakes.

Animal studies have shown that the strength released in eccentric phase raised with the increase in speed. Therefore, one could conclude after Ruiter and Haan [12], that the sooner the barbell was moved downward, the higher the force required for its control should be. However, other authors have reported that in humans the relation is not always occurring [12]. Gulch hypothesis says that the difference is due to the inhibition of the nervous system, which occurs in any muscle contraction. Such neural inhibition could lead to a reduction in the number of active motor units generating strength [13]. Research has confirmed that weight training can change the level of inhibition [14], but this advantage results from the decrease in the level of activation of antagonist muscles [15]. The task of inhibition was not known, but could have been a form of protection against excessive muscle tension because the amount of strength is the product of mass and acceleration. If the barbell weight increased and the maximum acceleration value remained unchanged, it could have suggested that the strength necessary for controlled lowering of the barbell also increased. This could also mean that released muscle strength in the eccentric movement was adequate or increased in proportion to changes in the barbell weight.

Changing the direction of the barbell's movement during the press meant the transition from eccentric to concentric work. Fast muscle stretching in „inhibited downward movement" phase influenced muscle proprioceptors, which increased priming of the motor neurons in these muscles by feedback, generating considerable elastic forces. Effective use of this phenomenon was only possible during sudden transition from the braking phase in downward movement to the upward barbell movement phase. However, the analyzed barbell movement did not allow the use of additional energy associated with the stretch reflex. This resulted from the regulations in this discipline, which said that the barbell has to stop on the chest. Therefore, the downward and then upward barbell movements needed to be treated as two separate ones. Consequently, competitors did not have the possibility to use stretch reflex when changing direction.

Cronin et al. [16] have analyzed the power and speed of movement execution, as the essential characteristics of weight training technique. They found out that the greater was the rate of concentric contraction, the lower was the strength possible to generate. Moreover, they believed that the barbell bounce off the chest was not essential for the average strength of the concentric phase, while increasing the maximum strength in the barbell bounce did not affect the medial strength during the press. They explained it with the fact that the maximum strength occurred very early in the concentric contraction and then the effect of stretching-contraction cycle was lost, if the movement lasted too long. Long stretch phases (above 0.5 sec.) were associated with a slow transition from eccentric to concentric work and loss of elastic energy. Similar results were reported by Newton et al. [4], who observed a considerable acceleration in the early concentric phase during the press at high speed and relatively low weight of the barbell. However, in the final phase of contraction, reduction in speed occurred. Consequently, considerable strength was generated only at a very short motion range.

The present study did not analyze how long did it take for acceleration to reach maximum value, but it can be said that it decreased along with an increase in the barbell weight. This could mean that slightly higher muscle activity during the concentric phase was necessary, particularly at heavier loads. It therefore seems reasonable to perform a greater number of repetitions with increased speed and barbell weight [4].

Downward barbell movement to the chest was performed by competitors with a similar speed in all barbell weights. Similar results occurred with the maximum acceleration. Strength generated during the lift depended on the speed and acceleration of the carried out movement. If we assume that the weight of the barbell increased and the other parameters remained unchanged, this means that the strength generated in eccentric movements increased in proportion to the barbell weight. However, during concentric movement the speed decreased with increasing barbell weight. This does not mean, however, that the strength generated during the upward movement did not grow in proportion to the increasing barbell weight.

During the upward barbell movement the acceleration was significantly higher than during the downward one, if the weight did not exceed 80% 1RM. With barbell weight of 95% 1RM maximum acceleration values differed insignificantly. Correlations between maximum acceleration during upward and downward barbell movements were relevant to the barbell weight of 80% 1RM. This means that the larger was the barbell inhibition when moving downward, the higher was the acceleration of the upward movement. However, such only occurs for the barbell weight not exceeding 80% 1RM.

*It can be therefore concluded that if the training process requires co-shaping of the motion technique and of any other motor skill demanding the use of larger barbell weights, it would be more beneficial to perform it while lowering the barbell. A more general statement can also be formulated - technique shaping can be more effective by using eccentric muscle work exercises. However, it should be remembered that merely two maximum exercises of an eccentric nature can cause a significant decrease in muscle strength* [17].

## CONCLUSIONS

Increasing the barbell weight did not result in significant changes in kinematic parameters during the downward movement, while in the upward movement barbell weight had a clear influence on changes in kinematic parameters. These changes were presented in the fact that the duration of the movement lengthened, while speed and acceleration values decreased with increasing the barbell weight.

## COMPETING INTERESTS

Authors have declared that no competing interest exists.

## REFERENCES


1. Sakamoto A, Sinclar PJ. Effect of movement velocity on the relationship between training load and the number of repetitions of bench press. J Strength Cond Res 2006; 20(3): 523-527
2. Szafraniec R, Samołyk A, Łuczak A et al. Wpływ treningu i wybranych zabiegów odnowy biologicznej na poziom wydolności beztlenowej niepełnosprawnych ciężarowców w podokresie przygotowania specjalnego. Rozprawy Naukowe AWF Wrocław 2012; 39: 90-95
3. Carpes FP, Bini RR, Mota CB. Training level, perception and bilateral asymmetry during multi-joint leg-press exercise. Braz J Biomotricity 2008; 2: 51-62
4. Newton R, Murphy A, Humphries B et al. Influence of load and stretch shortening cycle on the kinematics, kinetics and muscle activation that occurs during explosive bench press throws. Eur J Appl Physiol 1997; 75(4): 333-342
5. Chiu LZF, Schilling BK. A primer on weightlifting: prom sport to sport training. J Strength Cond Res 2005; 27(1): 42-48
6. Garhammer J. Barbell trajectory, velocity and power changes: Six attempt and four world records. Weightlifting 2001; 19: 27-30
7. Dohoney P, Chromiak JA, Lemire D at al. Prediction of one repetition maximum (1-RM) strength from a 4-6 RM and 7-10 RM submaximal strength test in healthy young adult males. J Exerc Physiol 2002; 5(3): 54-59
8. Dias RMR, Cyrino ES, Salvador EP et al. Influence of familiarization process on muscular strength assessment in 1-RM test. Rev Bras Med Esporte 2005; 11(1): 39-42
9. Lehman GJ. The influence of grip width and forearm pronation/supination on upper – body myoelectic activity during the flat bench press. J Strength Cond Res 2005; 19(3): 587-591
10. Hernández-Davó JL, Sabido R, Moya-Ramón M et al. Load knowledge reduces rapid force production and muscle activation during maximal-effort concentric lifts. Eur J Appl Physiol 2015; 115(12): 2571-2581
11. Seidel W, Zurowska A. An analysis of the barbell motion depending on its weight in disabled powerlifting. Balt J Health Phys Act 2014; 6(3): 193-198
12. Ruiter CJ, Haan A. Similar effects of cooling and fatigue on eccentric and concentric force-velocity relationships in human muscle. J Appl Physiol 2001; 90: 2109-2116
13. Seger JY, Thorstensson A. Electrically evoked eccentric and concentric torque-velocity relationships in human knee extensor muslces. Acta Physiol Scand 2000; 169: 63-69
14. Colson S, Pousson M. Isokinetic elbow flexion and coactivation following eccentric training. J Electromyogr Kinesiol 1999; 9(1): 13-20
15. Pousson M, Amiridis IG. Velocity-specific training in elbow flexors. Eur J Appl Physiol 1999; 80(4): 367-372
16. Cronin JB, McNair PJ, Marshall RN. Force – velocity analysis of strength – training techniques and load: implications for training strategy and research. J Strength Cond Res 2003; 17(1): 148-155
17. Nosaka K, Sakamoto K. The repeated bout effect of reduced-load eccentric exercise on elbow flexor muscle damage. Eur J Appl Physiol 2001; 85(1-2): 34-40
18. Bąk R. Definition of extreme physical activity determined through the Delphi method. Arch Budo Sci Martial Art Extreme Sport 2013; 9: 17-22


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