



## Neuromuscular Control During the Bench Press Movement in an Elite Disabled and Able-Bodied Athlete

by

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*The disabled population varies significantly in regard to physical fitness, what is conditioned by the damage to the locomotor system. Recently there has been an increased emphasis on the role of competitive sport in enhancing health and the quality of life of individuals with disability. One of the sport disciplines of Paralympics is the flat bench press. The bench press is one of the most popular resistance exercises used for the upper body in healthy individuals. It is used not only by powerlifters, but also by athletes in most strength-speed oriented sport disciplines. The objective of the study was to compare neuromuscular control for various external loads (from 60 to 100% 1RM) during the flat bench press performed by an elite able-bodied athlete and an athlete with lower limb disability. The research project is a case study of two elite bench press athletes with similar sport results: an able-bodied athlete (M.W., age 34 years, body mass 103 kg, body height 1.72 m, 1RM in the flat bench press 200 kg) and a disabled athlete (M.T., age 31 years, body mass 92 kg, body height 1.70 m, 1RM in the flat bench press 190 kg). The activity was recorded for four muscles: pectoralis major (PM), anterior deltoid (AD), as well as for the lateral and long heads of the triceps brachii (TBlat and TBlong). The T-test revealed statistically significant differences between peak activity of all the considered muscles (AD with  $p = 0.001$ ; PM with  $p = 0.001$ ; TBlat with  $p = 0.0021$  and TBlong with  $p = 0.002$ ) between the 2 athletes. The analysis of peak activity differences of M.W and M.T. in relation to the load revealed statistically significant differences for load changes between: 60 to 100% 1RM ( $p = 0.007$ ), 70 to 100% 1RM ( $p = 0.016$ ) and 80 to 100% 1RM ( $p = 0.032$ ). The flat bench press performed without legs resting firmly on the ground leads to the increased engagement of upper body muscles and to their greater activation. Isolated initial positions can be used to generate greater engagement of muscle groups during the bench press exercise and evoke their higher activation.*

**Key words:** bench press, muscle activity, internal structure, disabled athletes.

### Introduction

The disabled population varies significantly in regard to physical fitness, what is conditioned by the damage to the locomotor system. There are disabled individuals that move and function independently, as well as those that are affected by total disability and are entirely dependent on others. A major type of damage to the locomotor system includes spinal cord injuries (SCI), cerebral palsy and amputations. The development of medical sciences and technological advances have led to the extension of life expectancy and better

quality of life in people with locomotor system dysfunctions, equalizing their occupational and sporting opportunities with these of the healthy population (DeJong et al., 1991). Recently the disabled population has attracted much attention of researchers from different fields of science (Franceschini et al., 2012). The locomotor disability leads to a number of posttraumatic problems, both early and delayed, which stimulate the search for new methods of improving the life of disabled subjects.

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Sport and physical activity are widely accepted as necessary components of health. One of the many alternative forms of rehabilitation of the disabled includes competitive sports. Recently there has been an increased emphasis on the role of competitive sport in enhancing health and the quality of life of individuals with disability (Goldberg, 1995). One of the sport disciplines of Paralympics is the flat bench press. The bench press is an often recommended exercise for individuals with paraplegia, amputations and other locomotor dysfunctions. It is characterized by short-term, high intensity efforts which require significant development of muscular strength of the upper limbs and trunk. Paralympic powerlifters participate in the bench press, which consists of athletes lowering a barbell to the chest, holding it motionless, and then pressing it upwards to full arm extension. Athletes are given three attempts, with the winning athlete lifting the largest amount of weight (IPC 2015; Willick et al., 2016). Data regarding injuries for para-athletes participating in powerlifting are scarce (Athanasopoulos et al., 2009; Reynolds et al., 1994).

The bench press is one of the most popular resistance exercises used for the upper body in the healthy population. It is used not only by powerlifters, but also by athletes in most strength-speed oriented sport disciplines (Tillar and Ettema, 2013). In competitive bench pressing the result is represented by the maximal weight that can be lowered to the chest and lifted (pushed up) to the full extension of the elbow joints (Tillar and Ettema, 2009). The competitive bench press is connected with a very reproducible movement technique, which is perfected for many years of training. Various methods are used in bench pressing to improve the lifting technique which includes grip width, angle and bench, inclination angle variation. Dumbbells and an unstable surface are used to improve balance and coordination. The internal structure of the bench press exercise has been analysed and described extensively in the literature (Golas et al., 2016; Maszczyk et al., 2016; Sakamoto and Sinclair, 2012; Stastny et al., 2017). However, no studies have considered the analysis of muscular activity during the bench press movement in elite able-bodied and disabled athletes. Therefore, the objective of the study was to compare

neuromuscular control for various external loads (from 60 to 100% 1RM) during the flat bench press performed by an elite able-bodied athlete and an athlete with lower limb disability.

## Methods

### *Participants*

The research project is a case study of two elite bench press athletes with similar sport results: an able-bodied athlete (M.W., age 34 years, body mass 103 kg, body height 1.72 m, 1RM in the flat bench press of 200 kg) and a disabled athlete (M.T., age 31 years, body mass 92 kg, body height 1.70 m, 1RM in the flat bench press of 190 kg). The individual with lower limb disability performed the task according to the IPF (International Powerlifting Federation) regulations concerning the lift (bench press), used during international competitions for the disabled. The participants did not perform any additional resistance exercises for 72 hours prior to testing to avoid fatigue. The subjects were informed verbally and in writing about the procedures and possible risks of the tests and provided written consent before they were included in the study. The study received the approval of the Bioethics Committee at the Academy of Physical Education in Katowice, Poland.

### *Procedures*

The measurements were performed in the Laboratory of Muscular Strength and Power at the Academy of Physical Education in Katowice. There were two sessions of the experiment. Session 1 was aimed at determination of one repetition maximum during the flat bench press (1RM). Session 2 consisted of performing the flat bench press exercise with increasing loads (60 - 100% 1RM).

The procedure consisted of performing individual attempts of the flat bench press with an increasing load (from 60 to 100% 1RM) with 5 min rest periods between attempts. A standardized warm-up protocol was used for each session, including a general warm-up (5 min), using a hand cycle ergometer (heart rate of around 130 bpm) and performing several lower and upper body resistance exercises. The specific part of the warm-up consisted of three bench press sets with the load adjusted accordingly to perform 15, 10 and 5 repetitions.

The determination of 1RM was performed according to the protocol by Tillaar and Saeterbakken (2014). The percentage of the 1RM load was calculated based on the self-reported values by the participants. The self-reported 1RM was set according to the provided information regarding maximal lifts performed in the previous three months. The rest periods between sets were 5 minutes to avoid potential effects of fatigue. When the self-reported 1RM was successful, a trial with an additional load of 2.5-5 kg was performed. When the initial trial was unsuccessful, the weight was decreased by 2.5-5 kg. A total of two to three trials were performed per participant. Participants were instructed to maintain the head, shoulder blades and buttocks in contact with the bench at all time. Two experienced spotters assisted the athletes in the preload phases.

#### *Electromyography*

An eight-channel Noraxon TeleMyo 2400 system (Noraxon USA Inc., Scottsdale, AZ; 1500Hz) was used for recording and analysis of biopotentials from the muscles. The activity was recorded for four muscles: pectoralis major (PM), anterior deltoid (AD), as well as for the lateral and

long heads of the triceps brachii (TBlat and TBlong). Before placing the gel coated self-adhesive electrodes (Dri-Stick Silver circular sEMG Electrodes AE-131, NeuroDyne Medical, USA), the skin was shaved, abraded and washed with alcohol. The electrodes (11 mm contact diameter and a 2 cm center-to-center distance) were placed along the presumed direction of the underlying muscle fiber according to the recommendations by SENIAM (Hermens et al., 2000). The EMG signals were sampled at a rate of 1000 Hz. Signals were band pass filtered with a cut off frequency of 8 and 450 Hz, after which the root-mean-square (RMS) was calculated. All the electrodes were located on the right side of the participant, regardless of whether this was the dominant side or not. The grounding electrode was placed on the connection with the triceps brachii muscle. Video recording was used for identification of the beginning and completion of the movement. After completion of all the tests in a single day, 2-3 s evaluations of static bench press movements were performed in order to normalize electromyographic records according to the SENIAM procedure. The analysis was based on peak activity during the bench press (both from the eccentric and concentric phases).

**Table 1**

*Changes in peak muscle activity (%) of four muscles during the bench press with different loads (60%, 70%, 80%, 90% and 100% 1RM).*

Muscle/load	60% 1RM	70% 1RM	80% 1RM	90% 1RM	100% 1RM
DISABLED ATHLETE					
AD	69	70	88	94	118
PM	44	66	71	78	88
Tblat	40	63	62	74	86
TBlong	58	68	67	71	95
ABLE-BODIED ATHLETE					
AD	64	89	105	112	135
PM	111	113	115	116	110
Tblat	110	105	1	92	102
TBlong	65	71	74	82	105

Table 2

*Peak muscle activity differences in the able-bodied and disabled athlete in relation to load changes*

Load values (%1RM)	<i>p</i>
60 vs. 70	0.390
60 vs. 80	0.867
60 vs. 90	0.097
60 vs. 100	<b>0.007*</b>
70 vs. 80	0.589
70 vs. 90	0.311
70 vs. 100	<b>0.016*</b>
80 vs. 90	0.224
80 vs. 100	<b>0.032*</b>
90 vs. 100	0.094

\*  $p < 0.05$ .

### Statistical Analysis

The data were processed using Statistica software and presented as means with standard deviations. The Shapiro-Wilk, as well as Levene and Mauchly's tests were used in order to verify the normality, homogeneity and sphericity of the sample's data variances, respectively. The statistical analysis was aimed at determining the differences in muscle peak activity between the 2 participants using the T-test (Maszczyk et al., 2012, 2014, 2016; Przednowek et al., 2016). The statistical significance was set at  $p < 0.05$ .

### Results

Changes in peak muscle activity of four chosen muscles for analysis (AD, PM, TBlat, TBlong) during the bench press with different loads (60, 70, 80, 90 and 100% 1RM) are presented in Table 1.

The T-test revealed statistically significant differences between peak activity of all the considered muscles (AD with  $p = 0.001$ ; PM with  $p = 0.001$ ; TBlat with  $p = 0.0021$  and TBlong with  $p = 0.002$ ) between the 2 athletes.

The analysis of peak activity differences of M.W and M.T. in relation to particular loads revealed statistically significant differences for load changes between: 60 to 100% 1RM ( $p =$

0.007), 70 to 100 % 1RM ( $p = 0.016$ ) and 80 to 100% 1RM ( $p = 0.032$ ) (Table 2).

For the athlete with disability, the increase in the load from 70 to 100% 1RM led to an increase in activity of all the analysed muscles (for AD by 49%, for PM by 44%, for TBlat by 46% and for TBlong by 37%). In the able-bodied athlete, a similar increase in the load caused higher activity in the anterior deltoid and the long head of the triceps brachii (by 71% and 40%, respectively), while decreases in activity of the pectoralis major (PM) and lateral head of the triceps brachii were observed (TBlat; by 1% and 18%, respectively).

### Discussion

Resistance exercises elicit a combination of neural and muscular responses and adaptations (Kay et al., 2000). Workout variety increases motivation and long term adaptation, while avoiding monotony and overtraining (Crewther et al., 2005). Increased muscular activation resulting from training is most often ascribed to a combination of greater recruitment (the number of fibers involved in a muscle action) and higher rate coding (the frequency at which the motor units are stimulated; Enoka and Fuglevand, 2001; Enoka and Duchateau, 2015).

The results of our research indicate

statistically significant differences between the disabled and able-body athletes in peak activity of all muscles (AD, PM, TBlat, TBlong). Analysis of peak activity differences in relation to the lifted load revealed significant differences for load changes between: 60 to 100% 1RM, 70 to 100 % 1RM and 80 to 100% 1RM. For the able-bodied athlete our results are in accordance with the literature which indicates that an increase in the load during the standard bar bench press causes greater peak activation of the triceps brachii and anterior deltoid without significant increases in PM activation (Maszczyk et al., 2016; Saeterbakken et al., 2017). However, for the athlete with disability, higher loads caused increased activity of all the studied muscles, yet there is no relevant data in the literature in this regard (Stastny et al., 2017). These differences are most noticeable when changing to maximum loads.

Changes in EMG activity between the able-bodied and disabled athlete during the bench press movement are most likely related to tonic muscle control (Welsch et al., 2005). To perform a motor task the CNS activates particular muscle groups in a pre-determined sequence. However, activation of prime movers in a particular exercises is not always identical during changes of the external load (Stastny et al., 2016). Brennecke et al. (2009) suggest alternative principles of muscular activation during the same and progressive loads which have not been yet precisely explained. The first principle relates to minimal energy expenditure. The second principle is based on the prediction of external forces such as gravity, while the third one consists of muscle synergy between particular parts of the body. The recruitment of motor units and its firing frequency are controlled by central command of the CNS, and may be regulated by reciprocal feedback (Nichols et al., 1999).

For the athlete with lower limb disability, the change in the load from 70 to 100% 1RM led to an increase in activity of all the analysed muscles (for AD by 49%, for PM by 44%, for TBlat by 46% and for TBlong by 37%). In the able-bodied athlete, a comparable increase in the load caused higher activity in the anterior deltoid and the long head of the triceps brachii (TBlong by 71% and 40%, respectively), while a decrease in the activity of the pectoralis major (PM) and the lateral head

of the triceps brachii (TBlat; by 1% and 18%, respectively). For the athlete with lower limb disability, with a limited kinaesthetic sense and proprioception in this area, a compensation of deficits occurred, by increased synchronization of motor units and greater involvement of particular muscle groups during the bench press movement. The lack of support and lower limb muscle activation evoked greater muscle activation in the disabled athlete and a substantial stretch of the pectoralis major muscle. This could have been generated by a more flat lying position compared to the able-bodied athlete, which can result from reduced muscle tone in the back muscles. This difference in the lying position between the able bodied and disabled athletes at the elite level consequently led to a different movement structure during the flat bench press.

A methodological limitation of the study is the lack of possibilities for evaluation of the external structure of the movement (forces and movement torques), and small sample size (case study) which substantially reduces the opportunity for generalization. Future research in this area should concentrate on the analysis of the internal and external structure (Krol and Golas, 2017) of the bench press movement between able-bodied and disabled athletes.

## Conclusion

The flat bench press performed without legs resting firmly on the ground leads to the increased engagement of upper body muscles and their higher activation. Future research should concentrate on larger groups of subjects with various lower limb disabilities (amputations, palsies at various degrees). When evaluating muscle activity in disabled subjects during the bench press movement, both sides of the body should be analysed to determine possible asymmetry.

## Practical implications

Isolated initial positions can be used to generate greater engagement of muscle groups during the bench press exercise and evoke their higher activation.

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