

# Complex analysis of movement in evaluation of flat bench press performance

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The complex methodology of investigations was applied to study a movement structure on bench press. We have checked the usefulness of multimodular measuring system (SMART-E, BTS company, Italy) and a special device for tracking the position of barbell (pantograph). Software Smart Analyser was used to create a database allowing chosen parameters to be compared. The results from different measuring devices are very similar, therefore the replacement of many devices by one multimodular system is reasonable. In our study, the effect of increased barbell load on the values of muscles activity and bar kinematics during the flat bench press movement was clearly visible. The greater the weight of a barbell, the greater the myoactivity of shoulder muscles and vertical velocity of the bar. It was also confirmed the presence of the so-called sticking point (period) during the concentric phase of the bench press. In this study, the initial velocity of the barbell decreased ( $v_{\min}$ ) not only under submaximal and maximal loads (90 and 100% of the one repetition maximum; 1-RM), but also under slightly lighter weights (70 and 80% of 1-RM).

*Key words:* BTS measuring system Smart-E, electromyography, pantograph, bench press

## 1. Introduction

Information about the way of motor (sport) action is necessary for its analysis. Information is gained by an experienced teacher or coach as a result of visual observation. Collecting information requires the teacher to have certain abilities to observe motor actions. However, observation is not a reliable method, therefore recording or measurement of different parameters is used in scientific investigations of motor actions. Motor actions are estimated by using a number of accessible biomechanical methods.

The complex methodology of investigations was applied several times by us to study the movement structure in weight lifting [1]. The understanding of both external (kinematics and kinetics) and internal (the bioelectric activity of muscles) structure of snatch was acquired by a simultaneous application of force platform, electromyography, goniometers, video camera and other special devices. The technique of the movements

performed was described based on the results of the methods used. We focused on the mistakes as well as on changes in the structure of movement as a result of load variation.

SANTANA et al. [2] measured spine and right-hand (pressing-hand) kinematics with an electromagnetic tracking instrument. The machine was synchronized with the electromyography signals (EMG) of various shoulder's and torso's muscles during standing cable press (SCP). In the case of the one repetition maximum (1-RM) of a single-arm SCP, the left internal oblique and left *latissimus dorsi* activities were similar to those of the *anterior deltoid* and *pectoralis major* during flat bench press. The results of study seem to indicate that chest strength may not be the most important factor when pressing from a standing position.

Another study using a few measuring methods was carried out by REQUENA et al. [3]. They measured the effect of post-tetanic potentiation (PTP) induced in the *pectoralis* and *triceps brachii* muscles by high-frequency submaximal percutaneous electrical stimu-

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lation (PES) on average and maximal power attained in bench press throwing. REQUENA et al. suggest that PES application was not an effective stimulus for increased bench press performance. Simultaneously a great interindividual response was observed.

To identify the descent (eccentric) and ascent (concentric) phases during the bench press exercise LAGALLY et al. [4] place a goniometer on the lateral surface of the elbow to monitor joint flexion and extension. They collect EMG data as a measure of muscle activity which may moderate the responses to perceived exertion during resistance exercise.

Nowadays very popular is video technique (i.e. Simi, PEAK, Qualisys, VIDANA) synchronized with other measuring methods, which permits a complex analysis of movement.

In this study, we have checked the usefulness of multimodular measuring system (SMART-E, BTS Company, Italy) and special device to track the position of barbell (pantograph) in studying the structure of flat bench press and we also have compared the results of two measuring methods.

## 2. Material and methods

### 2.1. Subjects

Sixteen healthy men, whose sports skills were different, took part in our investigation. Participants were informed about the nature of this study and prior to data collection they were required to sign a consent form according to human subject regulations. The subjects performed a supine (flat) bench press (BP) using free weights and “touch-and-go” technique. All participants were considered to be recreationally trained lifters with power-lifting style of training. They made a few sets performed with big, submaximal and maximal loads combined with a wide range of rest intervals between sets (from moderate to long). All subjects had to have at least one year of weight lifting experience prior to the study and the ability to bench press at least 100% of their body weight once. In this study, the results of one of the participants are presented.

### 2.2. Instrumentation and data collection

*Exercise.* After a general warm-up, subject performed a specific warm-up that consisted of two sets of 6 repetitions of the flat bench press. During the

testing session, subject performed five sets with increasing weight until his 1-RM bench press (the maximal weight that a subject could lift for one repetition) was determined. The 1-RM was recorded as the maximum resistance that could be lifted throughout the full range of motion using a proper form once only. The 1-RM value was used to determine the other intensities that were used during the testing session. This session included four sets of one repetition of the flat bench press with 70, 80, 90, and 100% of maximal loads lifted (100, 115, 130, and 145 kg, respectively). The rest periods of 2–5 minutes between trials allowed a subject to avoid muscular fatigue.

For the BP, subject remained in the supine position with the head and trunk supported by the bench, the knees bent and the feet flat on the floor. The position of the hands on the barbell was constant – the distance between palms was 81 cm for all tasks. That is the greatest width of barbell hold allowed by regulations of International Powerlifting Federation. One research assistant acted as a spotter and was located behind the bench in case the subject was not able to lift successfully the weight. Subject grasped the bar equidistant from the middle, unracked the bar, then extended the arms fully to hold the bar for one second in the middle of the sternum. Then subject lowered the bar in a smooth, controlled manner to touch the chest at approximately nipple level and then pushed the bar upward until both elbows were fully extended. In addition, the vertebral column was not allowed to hyperextend during the lift. The principal investigator also visually detected completion of the barbell press at full elbow extension.

*Electromyography.* Before the lifting exercise, the skin was prepared for the placement of surface electrodes. Electrode sites were lightly sanded with abrasive paste and cleaned with alcohol prior to electrode placement. Two disposable surface electrodes were placed 2 cm over the motor points of the *pectoralis major* (PM), the *anterior deltoid* (AD), the lateral head of *triceps brachii* (TB), and the *latissimus dorsi* (LD) parallel to the muscle’s fiber direction. All electrodes remained in place until data were collected in four tasks. The EMG signals were sampled at 1 kHz rate and measured by Pocket EMG System (BTS Company, Italy). All active channels were of the same measuring range fitted to the subject (typically  $\pm 10$  mV). Analog signal was converted to digital with 16 bit sampling resolution and collected on measuring unit. After being captured the signals were transmitted immediately to computer via Wi-Fi network. Following data collection, the signals from each trial were stored on the hard drive and later analyzed using the Smart Analyzer software.

*Measuring system SMART and pantograph.* Multidimensional movement was analysed with the measuring system Smart-E (BTS, Italy) consisting of six infrared cameras (120 Hz) and the wireless module Pocket EMG for measuring muscle bioelectric activity. The levels of activity of the *PM*, *AD*, *TB*, and *LD* muscles during flat bench press were monitored by surface electrodes placed over the motor activation points of these muscles during the eccentric and concentric phases of each chest exercise. Modellings in 3D space as well as calculations of parameters were performed with Smart software (Smart Capture, Smart Tracker and Smart Analyzer, BTS, Italy). This modern system of movement performance analysis registered the complex view of the technique of motor task based on the appointed kinematic parameters and the internal structure of movement (recorded EMG signals). The set of passive markers permitting the calculation of some chosen parameters of barbell and subject were applied. Technical accuracy of the system after calibration process was 0.4 mm – it was the accuracy of measurement, i.e. the distance between two markers in 3D. Simultaneously, the tracking position of barbell was registered with a special device (pantograph<sup>1</sup>) to identify the eccentric and concentric phases and to calculate the kinematic and kinetic parameters and primarily to compare the results of different measuring systems. All measurements, and also the results, were synchronized in time across master central processing unit.

*Electromyography data reduction.* The electromyography signal was filtered (passband Chebyshev filter, 10–500 Hz), next full-wave rectified and integrated with RMS method (moving window, 100 ms). The IEMG (integrated EMG ( $\mu$ Vs)) was calculated for the eccentric and concentric phases of each lift.

### 3. Results

Effect of an increased barbell load on the kinematic bench press movement is clearly evident. Bar velocity during the eccentric and concentric phases of the press with 100, 115, 130, and 145 kg is presented in figure 1. As can be observed, it is decreased over the range of absolute (relative) 1-RM loads. Bar

velocity was slightly different in the eccentric phase of this exercise. During the bench press with slightly lighter loads (70 and 80% 1-RM) subject behaved variously, but in the bench press attempts with 90 and 100% 1-RM the similarity of the velocity–time curves was really considerable. The peak velocity during the concentric bench press decreased over the range of absolute loads.

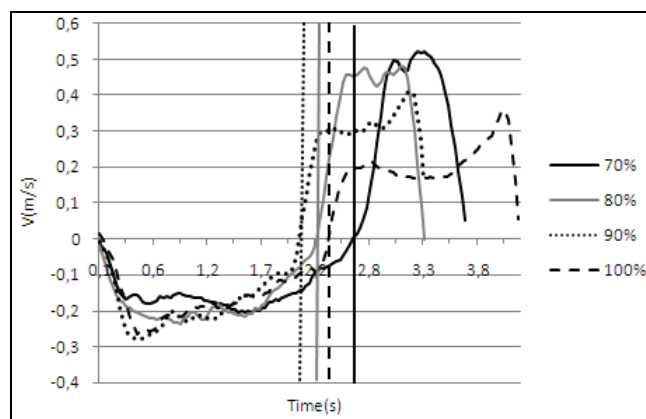


Fig. 1. Vertical velocity of the barbell's midpoint (m/s) for flat bench press with 70, 80, 90, and 100% of one repetition maximally lifted (1-RM)

The so-called sticking point<sup>2</sup> or sticking period observed in the concentric phase of the bench press trials is also interesting. In our research, we dealt with the sticking period at all (four) loads.

The myoelectric activity levels of the *pectoralis major* and the *anterior deltoid* muscles during the flat bench press with 100 to 145 kg were the highest in the eccentric phase of this exercise (figure 2). An increase in the weight of the barbell (from 100 to 145 kg) also resulted in an increase in the activity of the lateral head of the *triceps brachii*. The peak activation level of the *triceps brachii* was increased and “drifted” into the beginning of the concentric phase of the press with an increased barbell's weight. During the whole bench press with all loads lifted, the activity of *latissimus dorsi* was the least.

The comparison of the parameters registered with the Smart system as well as with the pantograph shows that the results obtained are in good agreement. The track of barbell's midpoint and its velocity in vertical plane are presented graphically (figure 3) for both methods.

<sup>1</sup> The construction and the operating principle of the pantograph and calculation procedure are presented in detail by NAWRAT [5].

<sup>2</sup> It is the scientific designation of the point where the initial velocity of the barbell as it blasts off the chest has decreased most, before it starts to increase again until the lifter lock out [6].

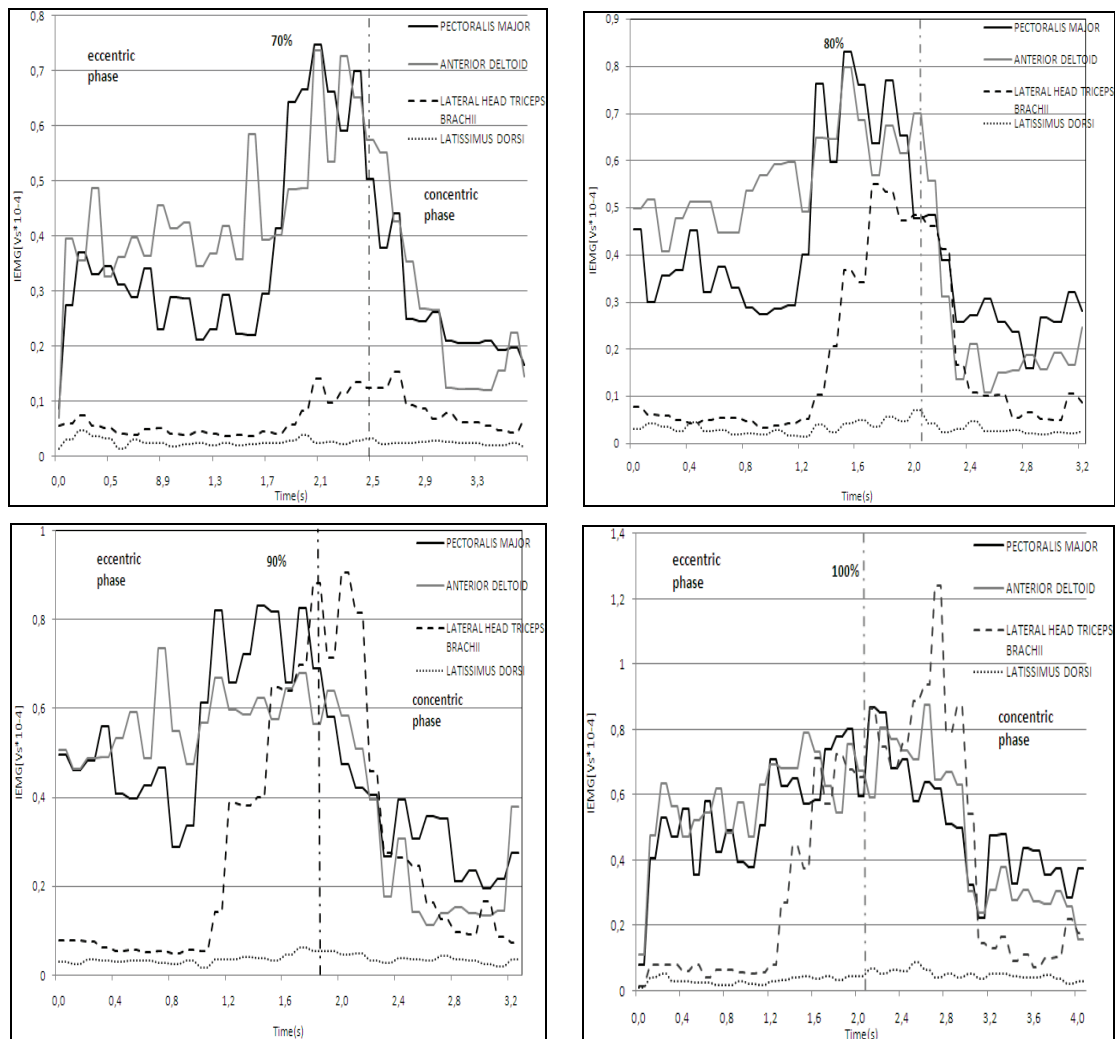


Fig. 2. Internal structure of movement – integrated electromyography (IEMG) from 4 muscles for flat bench press with 70 to 100% of the maximum weight lifted

## 4. Discussion

The modern measuring methods (SMART with Pocket EMG) in spite of their large complexity offer the complex measurement of the external and internal structure of movement. In the automatic process of data handling, the result of a simple movement can be obtained almost immediately. This is very important during the teaching of movement, because in short time the competitor or coach receives the “feedback” about executed task as well as mistakes, which were committed. Software Smart Analyser permits us to create database and to compare the chosen parameters (for example: the technique of novice competitors in comparison to the technique of advanced or master competitor). Results from different measuring devices are very similar, therefore the replacement of many devices by one multimodular system is reasonable. The data

handling in one space as well as ideal synchronization of all modules prove to be advantageous as well.

Synchronization of several modules (measuring devices) was permitted in the case of both external and internal structures (muscles activity) of the flat bench press analysis. The effect of increased barbell’s load on the values of muscles’ activity during the flat bench press movement was clearly visible. The heavier the load of the barbell, the higher the myoactivity (figure 2). The results of this study demonstrated that during the eccentric phase of the bench press the greatest activities of the *pectoralis major* and the *anterior deltoid* regardless of the barbell’s weight were recorded. Different activity of *pectoralis* was registered when the loaded barbell after the moving down (eccentric phase) with as much control as possible was touching the chest, and stopped before it is again moved up [7]. In these recent studies, *maximum pectoralis* activity was noted in the concentric phase of the press.

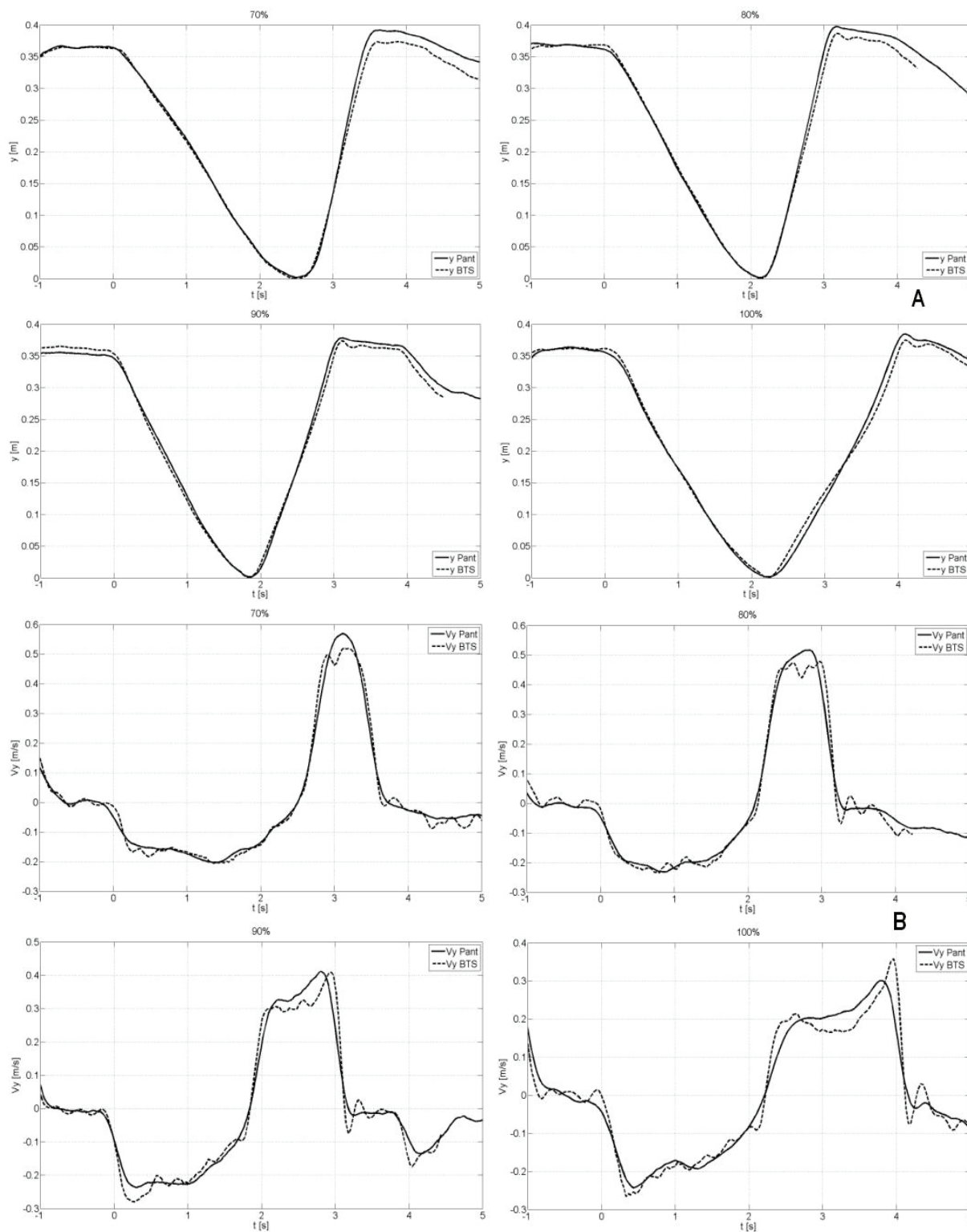


Fig. 3. The track of barbell's midpoint (A) and its velocity (B) in vertical plane for both methods (BTS Smart and pantograph)

In SANTANA's et al. [2] opinion, for the 1-RM bench press, *pectoralis major* and *anterior deltoid* were more activated than most of the trunk muscles. WELSCH et al. [8] concluded that the both muscles appeared to reach approximately the same peak acti-

vation level during the concentric phase of this exercise. This is also confirmed by our data.

Van Den TILLAAR and ETTEMA [6] said that *...Another study found that only in the chest and front portion of your deltoids do you experience significant*

contractions during the upward movement of the barbell. However, as you blast the barbell off your chest, there is actually peak muscle output coming from your triceps. In our work, the greatest activity during the concentric phase of the press with 90 and 100% 1-RM (130 and 145 kg, respectively) for the lateral head of *triceps brachii* was measured.

During the whole bench press with all weight lifted, the activity of *latissimus dorsi* was the smallest. BARNETT et al. [9] and LEHMAN et al. [10] also found a small activity of the *latissimus dorsi* during the performance of the push up.

Coordination of the shoulder's muscles during the flat bench press performance is responsible for movement kinematics of the barbell. As can be observed (figure 1), the bar velocity during the concentric phase of the press is decreased over the range of absolute 1-RM loads.

The sticking period [6] that can be observed in the concentric phase of the bench press trials is also interesting. It is the point where the initial velocity of the barbell as it blasts off lifter's chest has decreased most ( $t_{v_{min}}$ ). In Van Den TILLAAR's and ETTENA's [6] opinion, the sticking point was not present at loads of 75% 1-RM but was clearly visible at 90% loads. This is also partly confirmed by our data, but can be better exemplified by Word Champion [7].

## 5. Conclusion

Based on our own results and the results of other authors, as the final our conclusion we can accept the Van Den TILLAAR's and ETTENA's [6] statement: *...sticking point is caused not by a lack of muscle strength per se – as suggest some researchers – but by the delay in switching from maximal triceps contraction to maximal chest muscles and front deltoideus*

*contraction – as assume others. Moreover, the various muscles contribute to lifting at different rates.*

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