Flat bench press in the perspective of regression modeling

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Abstract: The main objective of the study was to identify statistically significant predictors of flat bench press and define a regression function in order to create a regression model describing the sports discipline. Twenty elite athletes participated in this investigation. All subjects were required to have at least 5-year weight lifting experience and the ability to bench press at least 100% of their body weight. The findings of the study indicated the following predictors as the most significant to determine the flat bench press results : the minimum right elbow joint angle during the descent phase of the lift, the minimum right elbow joint angle during the ascent phase, maximum speed of the descent phase and changes in the bar midpoint position during the descent phase. These four predictors might prove extremely useful for the coach in order to improve flat bench press technique and thereby, the athlete's result. The 12 statistically significant predictors of flat bench press constitute the input data to create a regression model describing the sports discipline.

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1. Introduction

The flat bench press is one of the three lifts in powerlifting being at the same time a separate event of the World Benchpress Championships. As a basic exercise to develop an athlete's motor abilities (strength, strength-speed and strength-endurance), it has also been an adjunct to training in other sport disciplines. Results obtained by the athletes during competitions mainly depend on the level of motor abilities (strength) developed during many years of training, psychological factors, the ability to use strength in movement, and also, although to a lesser extent, on the tactic of successive attempts to lift the weight.

The training process is aimed at constant improvement of athletes' skills and therefore their performance is continually assessed. When an activity is evaluated based on visual observation, as it is in the case of teaching and perfecting movements as well as during the evaluation of the athlete's performance, the observers often rely on the so called movement variables (Meinel et al., 1984; Król et al., 2010), which apply both to the athlete and the device they use. The most useful among these are variables commonly referred to as technique efficiency criteria, which constitute the basis for evaluating the efficiency of a given movement.

In order to analyze movement activities in sport one must have enough data concerning the performance thereof (Santana, 2007). An experienced teacher or coach gains such information through visual observation, which, however, requires some particular skills and is not objective. Therefore, research studies register or measure a number of variables using several biomechanical analyses. As no two movements are identical, in order for an assessment to be accurate and to provide valuable practical information resulting in sport technique improvement, a direction of change of a given variable as well as its minimum or maximum values must be determined (Lehman, 2005; Amanović et al., 2006). The evaluation of physical performance is often used to identify talent, develop training regimens, and quantify training adaptations (Roczniok et al., 2007; Roczniok et al., 2013).

Available literature provides little information on the movement of the barbell midpoint or spatiotemporal changes during the barbell bench press (Reynolds et al., 2006; Lima et al., 2008; Trebs et al., 2010). The purpose of this study was to investigate the direction of changes in kinetic and kinematic variables during barbell bench press in order to improve flat bench press results. The identification of changes in the barbell position might help establish the model of flat bench press. No such a model has so far been built, which considerably limits the knowledge on the principles of this movement activity. The objective of building the model would be to help determine the most important predictors of the dependent variable (ie., sports result), which, in flat bench press, is the maximum amount of weight an athlete is able to lift (ie., 1RM). It is quite obvious that such a model might not be effective for all athletes, but the study group consisting of instructors specializing in strength sports, was deemed an appropriate and representative sample for creating the model (Maszczyk et al., 2011, 2012).

The main objective of the study was to identify statistically significant predictors of flat bench press and define a regression function in order to create a regression model describing the sports discipline.

2. Material and Methods

Subjects

Twenty elite athletes participated in this investigation. All participants were informed about the aims and procedures of the study and, prior to data collection, they were asked to sign an informed consent form in accordance with human subject research regulations. The study subjects performed a flat bench press exercise (BP) using free weights and "touch-and-go" technique. All subjects were required to have at least 5-year weight lifting experience, and the ability to bench press at least 100% of their body weight.

Instrumentation and Data Collection

Exercise

After a general warm-up, the subjects performed a specific warm-up that consisted of two sets of 6 repetitions of the flat bench press. During the testing session, each participant performed five sets with increasing load until his 1-RM bench press (1-RM is used to indicate the most weight you can lift for one repetition) was determined. The 1-RM was defined as the maximum resistance that could be properly lifted throughout the full range of motion only once. The 1-RM was used to determine the other intensities that were applied during the testing session, and to create the regression model. The testing session included four sets of one repetition of the flat bench press with 90 and 100 % of maximum loads lifted. During these tests the discrimination analysis was used to determine the best discriminants for each of the loads, respectively. Rest periods of 2-5 minutes between following trials were allowed in order to avoid muscular fatigue.

For the BP, the subject was positioned supine 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 the International Powerlifting Federation. One research assistant acted as a spotter standing behind the bench in case the subject would not be able to successfully lift the weight. The subjects held the bar equidistant from the center of the bar, then extended the arms fully to hold the bar for 1 second in the middle of the sternum. Afterwards, they lowered the bar in a smooth, controlled manner to the chest and pushed the bar upwards until both elbows were fully extended. 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. Since the indirect aim of our investigation was to determine the variables of flat bench press to enhance the development of motor abilities, the athletes did not stop the movement of the barbell at the chest level.

Electromyography

Before the lifting exercise, the skin was prepared for placement of surface electrodes. First, electrode sites were lightly sanded with abrasive paste and cleansed with alcohol. Two disposables surface electrodes were placed 2 cm apart over the motor points of the pectoralis major (PM), anterior deltoid (AD), the lateral head of the triceps brachii (TB), and the latissimus dorsi (LD) parallel to each 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 the Pocket EMG System (BTS Company, Italy). All active channels were of the same measuring range (typically +/- 10mV). Analog signals were converted to digital with 16 bit sampling resolution and collected on the measure unit. The signals were transmitted immediately to the computer via the 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 analysis was carried out with the measuring system Smart-E (BTS, Italy) which consisted of six infrared cameras (120Hz) and the wireless module Pocket EMG for measuring muscle bioelectric activity. PM, AD, TB, and LD activity levels during flat bench press were monitored by surface electrodes placed over the motor activation points of these muscles during the eccentric and concentric phase of each chest exercise. 3D space modeling as well as parameter calculations were performed with the Smart software (Smart Capture, Smart Tracker and Smart Analyzer, BTS, Italy). This modern system of movement performance analysis registered the technique of the motor task based on the selected kinematic variables and the internal structure of movement (recorded EMG signals). Several passive markers allowing the calculation of some selected barbell and subject parameters were applied. Technical accuracy of the system after calibration was 0.4 mm. Simultaneously, the tracking position of the barbell was registered using a special device (pantograph) in order to identify the eccentric and concentric phases, to calculate the kinematic and kinetic variables, and primarily to compare the results obtained with different measurement systems (Nawrat, 2001). All measurements, and also results, were synchronized in time across a central master processing unit.

Electromyography Data Reduction

The electromyography signal was filtered (passband Chebyschew filter, 10-500Hz), full-wave rectified and integrated using the RMS method (moving window, 100ms). The IEMG (integrated EMG [μVs]) was calculated for the eccentric and concentric phase of each lift.

Data collection

In order to test the hypothesis, multidimensional statistical analyses were applied to results obtained in the study group. The values of variables measured by means of a robust measure of scale were used in multiple regression models. The research problem was addressed using empirical and predictive investigation based on the data obtained in the form of a multidimensional vector of variables, including independent Xn variables and one dependent variable Y, ie., the bench press result (BPR). Based on the results obtained by 20 study participants, mathematical models were created. Numerous characteristics of the participants such as body build, general and specific physical fitness were measured as independent variables. The most important variables were determined during the electromyography measurements which enabled the identification of 42 variables. In order to determine the optimal set of predictors, the vector R0 was determined for the independent variables and the vector R1 for the correlations generated by the vector R0 for variables showing a significant correlation with the dependent variable Y, ie., the bench press result.

This approach allowed the determination of 16 predictors which significantly improved the model's explained variable Y, ie., the bench press result. However, four variables were removed from the model following statistical testing (hypothesis testing, significance testing and statistical verification of structural parameters of the regression equation for a dependent variable Y- within the meaning of the equation: sign (r(xj,y))=sign (aj)).

Statistical analysis

Means and standard deviations were calculated for all variables. The Kolmogorov-Smirnov test of normality and Leavene's test of homogeneity of variance were used to verify the normality of the distribution. Stepwise multiple regression was used to select explanatory variables ensuring the best prediction of results in the model construction phase. Ultimately, twelve predictor variables were used to form regression models predicting Y (results of bench press); see Table 1 for details. The level of significance for all analyses was set at $p \leq 0.05$. All statistical analyses were carried out on a PC using the statistical package Statistica 9.1, and Excel 2010 from the Microsoft Office 2010.

3. Results

The analysis of measurement results using the Kolmogorov-Smirnov test revealed normal distribution of the study variables. Thus, multidimensional analytical methods were applied. Ridge regression determined 12 statistically significant predictors of the dependent variable, ie., the bench press result (Table 1).

Table 1. Regression statistics of regression model for Y, ie., *the bench press result* (twelve predictors)

Variables	β	SE β	B	SE B	*t*	*p*
Intercept			-239	103	-2.31	0.032
VmaxD	-1.43	0.39	-228.1	62.31	-3.66	0.002
LAmaxA	0.46	0.19	1.59	0.66	2.41	0.026
Za	0.86	0.16	0.42	0.08	5.22	0.000
Zd	-0.50	0.22	-0.33	0.149	-2.24	0.037
Yd	-1.30	0.36	-0.44	0.12	-3.55	0.002
RAminD	-3.81	1.10	-8.36	2.41	-3.45	0.003
RAmaxD	0.75	0.19	2.74	0.70	3.91	0.001
LDD	0.52	0.19	280.92	107	2.62	0.017
LAminD	0.87	0.32	1.87	0.70	2.67	0.015
RAminA	2.15	1.02	4.68	2.23	2.09	0.050
ADA	0.91	0.27	68.68	20.65	3.32	0.004
AmeanD	0.88	0.30	59.57	20.42	2.91	0.009

SE- standard error

The accuracy of the created model was confirmed with R=0.94 and R2=0.87 meaning that the model accounted for 87% of the variability of the phenomenon under investigation at F=6.79 and p<0.005. The model and predictors were verified using the highest reliability test based on the logarithmic Poisson distribution.

The model determined using the regression function had the following form:

Y(BPR)= -239 – 228.1*VmaxD + 1.59*LAmaxA +0.42*Za – 0.33*Zd – 0.44*YD – 8.36*RAminD +2.74*RAmaxD +280.92*LDD +1.87*LAminD +4.68*RAminA+68.68*ADA+59.57*AmeanD ±9.40

Regression analysis of the dependent variable based on the standardized and raw data revealed identical values of the predictors determined. However, raw data are considered more useful in the case of the training situation; thus, the model was based on raw values. According to the function equation, the bench press result will depend on the following predictors: **VmaxD** – maximum speed of the descent (Beta=1.43), **LAmaxA** – maximum left elbow joint angle during the ascent phase (Beta=0.46), **BzA** – changes in the bar midpoint position (horizontal plane) from the shoulders towards the nipples during the ascent phase (Beta=0.86), **BzD** – changes in the bar midpoint position (horizontal plane) towards the nipples during the descent phase (Beta=0.50), **ByD** – changes in the bar midpoint position (vertical plane, ie., up-down) during the descent phase (Beta=1.30), **RAminD** – minimum right elbow joint angle during the descent phase (Beta=3.81), **RAmaxD –** maximum right elbow joint angle during the descent phase (Beta=0.75), **LDD** – latissimus dorsi activity during the descent phase (Beta=0.52), **LAminD** – minimum left elbow joint angle during the descent phase (Beta=0.87), **RAminA** – minimum right elbow joint angle during the ascent phase (Beta=2.15), **ADA** – anterior deltoid activity during the ascent phase (Beta=0.91)**,** $\mathbf{A_{mean}D}$ - mean acceleration during the descent phase (Beta=0.88). The above mentioned predictors of the bench press result may prove very important to coaches in order to improve the athlete's technique of flat bench press.

4. Discussions

The aforementioned analyses resulted in the determination of several relationships between variables under investigation, which allowed to create a model of flat bench press.

To the authors' knowledge, there is no scientific papers attempting to create such a deterministic model; consequently, the knowledge with regard to this particular movement activity remains incomplete. The objective of the model is to help determine the most important predictors of the dependent variable, which, in flat bench press, is the maximum amount of weight the competitor is able to lift (ie. highest 1RM's values). It is quite obvious that such a model might not be effective for all athletes, but the study group consisting of instructors specializing in strength sports was deemed an appropriate and representative sample for creating the model.

The regression model presented in this article identified 12 predictors as the most important in bench press (results section above). The results of our analysis were in accordance with the conclusions of Reynolds et al. (2006), and Requena et al. (2005). Unfortunately, there is little data about the application of regression and discrimination models in powerlifting (as noted above), thus, it is difficult to compare our results to others. Therefore, it is noteworthy that these variables significantly influenced sports results in the analyzed group of the athletes.

For example, the articles focuses on the study which differentiates the results between electromyography (EMG) and kinematics techniques in maximal bench press training at one repetition maximum (1RM) in recreational weight-trained persons (van den Tillaar and Ettema, 2009). During an experimental research, scientists have speculated that failure of kinematics would occur during the sticking period due to the temporary reduction in movement velocity. In addition, it found that muscle activity showed equal pattern in both attempts and only differed during the downward and upward movement of the weight lifting. However, it states that the occurrence of failures are not always during the sticking period.

The purpose of the Lander et al.'s (1985) study was to evaluate selected variables describing performance characteristics of a free-weight and isokinetic bench press. A secondary purpose was an attempt to clarify the technique requirements essential for a successful lift. Variables describing the free-weight condition were generated from cinematographic data (150 fps) registered during five trials each at 90 and 75% of the subject's maximal performance (1RM). Isokinetic data were obtained from an instrumented Cybex Power Bench Press at two speeds corresponding to the average speeds for the free-weight conditions. Despite differences, accommodation appeared to occur for both methods when the lifts were performed maximally. A "sticking region" was defined as the portion of the free-weight activity when the subjects' force application was less than the weight of the bar. No significant difference (p less than 0.05) was observed between the 90% 1RM (26.02%) and 75% 1RM (26.94%) mean relative time values for these regions. For the Cybex device, the percentage of the activity which was isokinetic was longer for the slower speeds of rotation (0.47 rad X s-1 = 70%) and steadily decreased until the movement was only 50% isokinetic at 1.74 rad X s-1. The observed relationships between applied force-time data along with anatomical considerations suggest an ideal technique for the lift.

Many mathematical models have been used to understand and predict the complex relationships between variables (Kotb, 2012). In the present study, the regression analysis of the dependent variable based on the standardized and raw data revealed identical values of the predictors determined. However, raw data are considered more useful in the case of the training situation; thus, the model was based on raw values.

According to the function equation, the bench press result depends on several predictors. So far, the majority of researchers have believed that the activity of the pectoralis major (PM) and latissimus dorsi (LD) during the descent phase is the most important predictor to determine the bench press result (Bak et al., 2000; Lehman et al., 2006). Analysis of the regression function in the present study revealed that a one-unit increase in LD activity (EMG) should result in a load increase by 280kg (SE ±107kg). However, despite their significance, the latissimus dorsi and pectoralis major exhibit very low bioelectrical activity, which negates their essential role in flat bench press.

The other variables in order of importance are:

- the maximum speed of bar descent ($V_{max}D$); decreasing this variable by 1 unit should increase the flat bench press result by 228.1kg (SE±62.3kg);
- the activity of the anterior deltoid during the ascent phase of the lift (ADA); a one-unit increase (EMG) should increase the athlete's result by 68.68kg (SE±20.66kg). The activity of the anterior deltoid is the most important muscle-related predictor of the flat bench press result;
- the mean acceleration during the descent phase ($A_{mean}D$); its increase by 1 unit (m/s^2) should improve the result by 59.58kg (SE±20.42kg);
- the minimum right elbow joint angle during the descent phase ($RA_{min}D$); a one-degree decrease should result in a load increase by 8.36 kg (SE±2.41kg);
- the minimum right elbow joint angle during the ascent phase ($RA_{min}A$); a one-degree increase should improve the flat bench press result by 4.68kg (SE±2.23kg);
- the maximum right elbow joint angle during the descent phase ($RA_{max}D$); a one-degree increase should improve the flat bench press result by 2.75kg (SE±0.7kg);
- the minimum left elbow joint angle during the descent phase ($LA_{min}D$); a one-degree increase should improve the bench press result by 1.88kg (SE ±0.7kg);
- the maximum left elbow joint angle during the ascent phase ($LA_{max}A$); a one-degree increase should improve the flat bench press result by 1.6 kg (SE ±0.7kg);
- changes in the bar midpoint position (vertical plane, ie., up-down) during the descent phase (B_yD); a one-unit (mm) decrease should increase the athlete's result by 0.44kg (SE±0.12kg);
- changes in the bar midpoint position (horizontal plane) from the shoulders towards the nipples during the ascent phase (B_zA); a one-unit (mm) change should increase the result by 0.42kg (SE±0.08kg);
- changes in the bar midpoint position (horizontal plane) towards the nipples during the descent phase (B_zD); a one-unit (mm) decrease should improve the result by 0.33kg z (SE±0.14kg).

The findings of the study indicated the following predictors as the most significant to determine the flat bench press results: the minimum right elbow joint angle during the descent phase of the lift **[Beta= -3.81]**, the minimum right elbow joint angle during the ascent phase [**Beta=2.15**], maximum speed of the descent phase **[Beta= -1.43]** and changes in the bar midpoint position (vertical plane, ie., up-down) during the descent phase **[Beta= -1.30]**. These four predictors might prove extremely useful for the coach in order to improve flat bench press technique and thereby also the athlete's result. The 12 statistically significant predictors of flat bench press constitute the input data to create a regression model describing the sports discipline.

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