

Original research papers

MOVEMENT FEATURES WHICH DESCRIBE THE FLAT BENCH PRESS

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Abstract

Introduction. In sport technique studies, motion features can be useful as they have a certain defined measure [1]. In this work, we examined the following three features: the structure of the movement (all the characteristics of the movement), the fluency of the movement, and the rhythm of the movement. The aim of the study was to determine the usefulness of the selected movement features in the evaluation of the flat bench press. The protocol of the study included a flat bench press with free weights and a “touch-and-go” technique. **Material and methods.** The study involved twenty healthy men; however, only two were selected for analysis. The first subject was a 25-year-old powerlifter (body mass = 95 kg; body height = 182 cm; 1-RM in flat bench press = 145 kg). The second one was a 25-year-old bodybuilder (body mass = 77 kg; body height = 175 cm; 1-RM in flat bench press = 100 kg). The subjects performed consecutive sets of a single repetition of flat bench pressing with an increasing load (70, 80, 90, and 100% 1-RM, with the anticipated maximum weight), until the completion of one repetition maximum. Multidimensional movement analysis was made with the measuring system Smart-E (BTS, Italy), which consisted of six infrared cameras (120 Hz) and a wireless module to measure muscle bioelectric activity (Pocket EMG). **Results.** It was demonstrated that the internal structure of the bench press performed by the bodybuilder and the powerlifter was different. As the time-history of barbell kinematics (the acceleration-time curve) showed, with increased loading of the barbell, the rhythm of the flat bench press changed, and the fluidity of the movement worsened.

Key words: biomechanical analysis, comprehensive methodology, flat bench press, movement features

Introduction

Quantitative biomechanical movement analysis mainly uses the temporal characteristics of mechanical parameters. However, to effectively communicate with the athletes, the coaches often refer to the so-called movement features [1]. These features are primarily used in the qualitative analysis of sports activities. Movement features can also be useful in sport technique studies, as they have a certain defined measure. As a basis for consideration and analysis, we accepted a modified eight-element hierarchical classification of movement features [2]. Three groups of movement features can be distinguished here: the parent feature (the general basic structure), the complex features (the rhythm and motion coupling), and the elementary features (the fluency or “fluidity”, the accuracy or “exactitude”, the constancy, the rate, and the extensiveness of motion). The most informative feature, which is at the same time

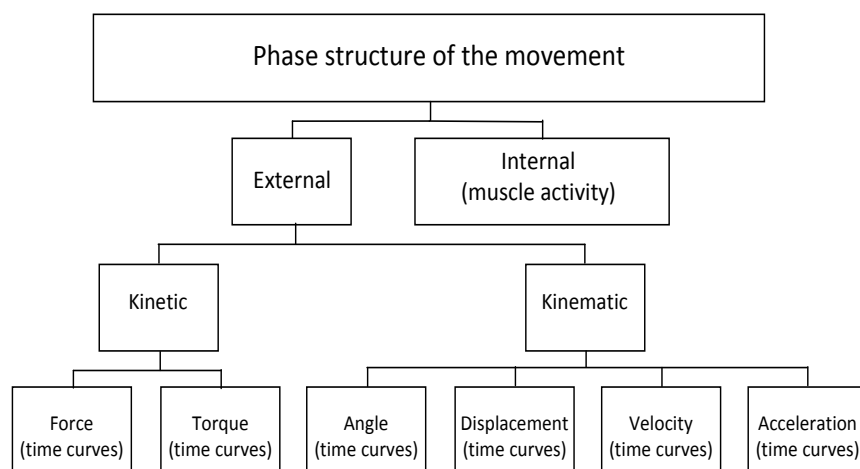


Figure 1. Phase structure of the movement – all the characteristics of the movement

very readable and useful in the evaluation of the movement, is the structure of the movement. The spatio-temporal structure of the movement is the only structure available to the observer. The assessment of this parent (overriding) and the generalised categories of description, based only on visual observation, is relatively simple, but informationally poor. Therefore, research on sport techniques should cover both the causes of motion (the internal and external kinetic structure of the movement – all the characteristics of the movement, shown in Figure 1) and the external kinematic structure of the movement that shows the effects of the motion. Equally important in the evaluation of sports techniques are other features, for example: the rhythm, the accuracy, and the fluidity of the movement.

The aim of the study is to determine the usefulness of the selected movement features in the evaluation of the flat bench press.

Material and methods

Twenty healthy college-age recreational weight trainers volunteered to participate in this study [3]. Since the assessment and improvement of techniques concerning sports activities always refer to a specific person, the paper presents the characteristics of the movement features for the representatives of two power sport disciplines. The first representative was a 25-year-old powerlifter. His body mass was 95 kg, and his body height was 182 cm. The second subject was a 25-year-old bodybuilder. His body mass was 77 kg, and his body height was 175 cm. The research project was approved by the Committee of Bioethics of the Academy of Physical Education in Katowice, Poland. Both subjects signed an informed consent document prior to beginning the study.

The protocol included a flat bench press with free weights and the “touch-and-go” technique. The data for the study were collected during two sessions: the warm-up and the main session. After a general warm-up (a 10-minute run on the treadmill and stretching), both subjects performed a specific warm-up that consisted of three sets of 10 to 5 repetitions with light weights selected by the subjects (at 40-60% 1-RM¹ of the flat bench press). In the main (measuring) session, the participants performed consecutive sets of a single repetition of flat bench pressing with an increasing load (70, 80, 90, and 100% 1-RM, with the anticipated maximum weight), until the completion of one repetition maximum. In the case of the powerlifter, the mass of the barbell was, respectively, 100, 115, 130, and 145 kg. In the case of the bodybuilder, the mass of the barbell was, respectively, 70, 80, 90, and 100 kg. The rest periods between the sets on the bench press lasted about 3 min. Both participants used a grip that was 81 cm wide between the forefingers, in accordance with the International Powerlifting Federation's special requirements. A spotter assisted the men in lifting the bar from a support rack, but they were not assisted by the spotter during the lift. The subjects lowered the barbell in a smooth, controlled manner and touched the chest before returning to full arm extension. The athlete was instructed to perform the bench press with full commitment.

We followed the methods of Król and Gołaś [3], and a multidimensional movement analysis was made with the measuring system Smart-E (BTS, Italy), which consisted of six infrared cameras (120 Hz) and a wireless module to measure muscle bioelectric activity (Pocket EMG).

Kinematics

The set of passive markers reflecting the infrared radiation (IR), permitting the calculation of some chosen parameters of the barbell and subjects, were applied. Modellings in 3D space as well as calculations of parameters were performed with Smart software (Smart Capture, Smart Tracker, and Smart Analyzer, BTS, Italy). After the calibration process, the technical accuracy of the system was 0.4 mm – it was the accuracy of measurement, i.e. the distance between two markers in 3D. After smoothing the registered deterministic trajectory of the barbell (weighted average), we also smoothed the velocity and acceleration curves of the barbell.

Electromyography

The EMG signals were measured and sampled at a 1-kHz rate using a Pocket EMG System (BTS, Italy). All active channels were the same, and the measuring range was fitted to the subject (typically ± 10 mV). The analogue signal was converted into a digital one with a 16-bit sampling resolution. After being captured and converted, the signals were transmitted immediately to the computer via a Wi-Fi network. Following data collection, the signals from each trial were stored on the hard drive and later analysed using the Smart Analyzer software. The participant's skin was specially prepared (lightly sanded with abrasive paste and cleaned with alcohol) where the disposable surface mounting electrodes were to be located. The electrodes were placed where there was motor activation of the muscles (according to the direction of the fibres, in accordance with the European Recommendations for Surface Electromyography – SENIAM) [5].

All electrodes were placed on the right side of the subjects' bodies. These electrodes were supposed to monitor the level of involvement of the following muscles: *pectoralis major*, *anterior deltoid*, *long head of triceps brachii*, and *latissimus dorsi*. Using the start, midpoint, and endpoint, identified from the BTS System data recorded for each trial, the integrals of the linear envelope in mVs (IEMG: integrated EMG computed at time intervals of 0.1 s) were calculated over the descent and ascent phases for each muscle during each trial. All measurements, and also the results, were synchronised in time across the master central processing unit.

Results

Already in the preliminary analysis of the data, clear differences in the activity of the muscles of individual subjects were revealed (Fig. 2A and 2B).

Another difference was seen in the internal structure of the movement. The timing charts of the *triceps* were especially distinctive. If the load increased, the IEMG activity of the *triceps* also increased. Only in the case of the powerlifter did the increase take place at the end of the descent phase (Fig. 2A). In the case of the bodybuilder, the increase took place up to the beginning of the ascent phase (Fig. 2B). It is also interesting that in the attempt at a load corresponding to 100% 1-RM, the involvement of the *pectoralis major* in this phase initially decreased very clearly and only then increased (Fig. 2Bd). The timing charts of the acceleration and velocity of the barbell (kinematic structure of the movement) are shown in Figures 3A and 3B as well as Figures 4A and 4B, respectively.

The acceleration-time curves are particularly interesting, as they illustrate the fluidity of the movement [6]. The temporal relationship between the successive phases – the rhythm of the movement [1] – as could be expected, was different for each of the athletes (Tab. 1).

¹ 1-RM – one repetition maximum – the maximal weight that a subject could lift for one repetition [4].

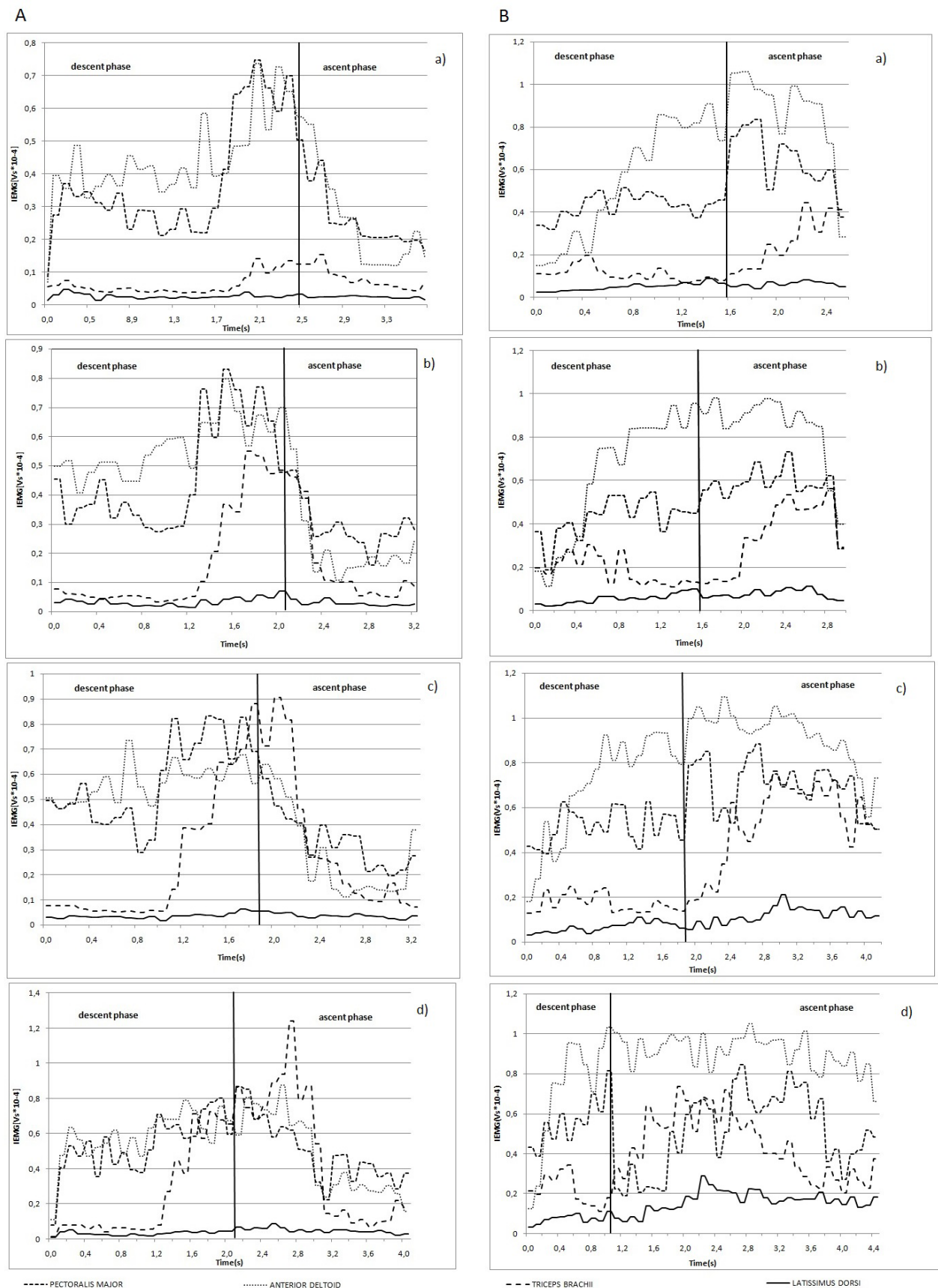


Figure 2. Integrated electromyography signals (computed at time intervals of 0.1 s) for four muscles. A – powerlifter; B – bodybuilder. Attempts at the following loads: a) 70% 1-RM; b) 80% 1-RM; c) 90% 1-RM; d) 100% 1-R

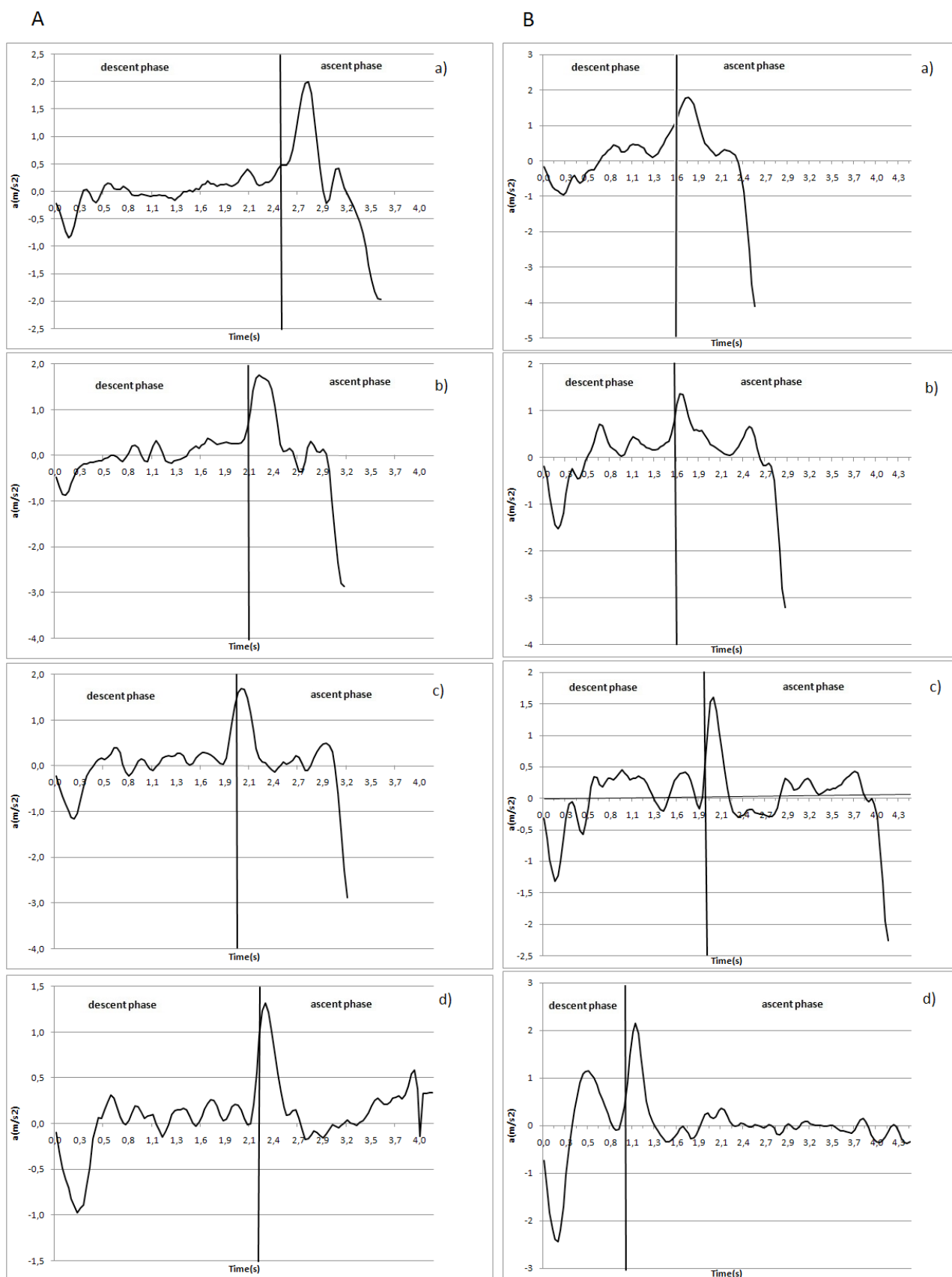


Figure 3. Acceleration-time curves: A) powerlifter; B) bodybuilder. Attempts at the following loads: a) 70% 1-RM; b) 80% 1-RM; c) 90% 1-RM; d) 100% 1-R

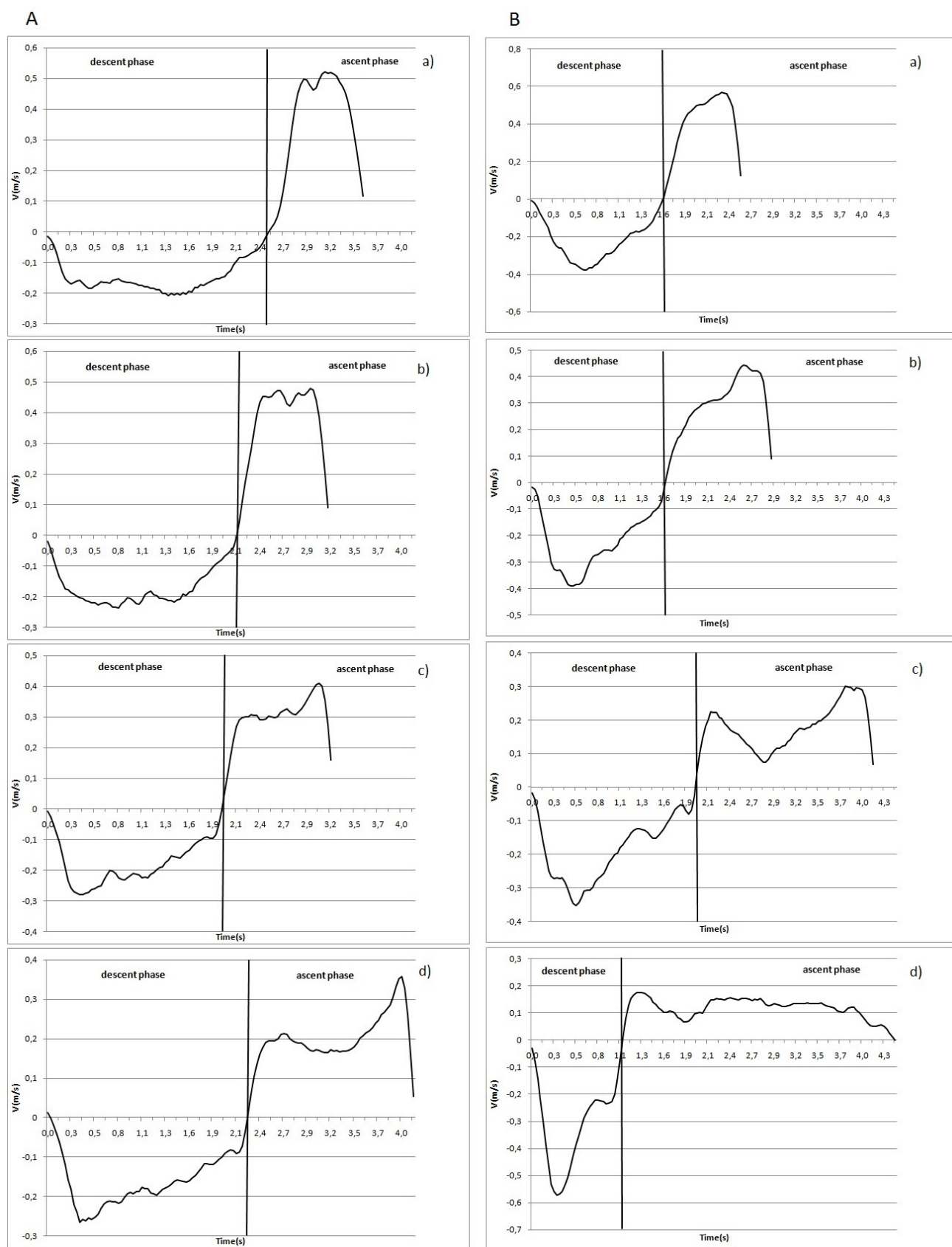


Figure 4. Velocity-time curves. A – powerlifter; B – bodybuilder. Attempts at the following loads: a) 70% 1-RM; b) 80% 1-RM; c) 90% 1-RM; d) 100% 1-R

Table 1. Phase durations for the two phases of the flat bench pressing of each of the athlete

Athlete	Loads pressed							
	70% 1-RM		80% 1-RM		90% 1-RM		100% 1-RM	
	Descent phase (s)	Ascent phase (s)	Descent phase (s)	Ascent phase (s)	Descent phase (s)	Ascent phase (s)	Descent phase (s)	Ascent phase (s)
Powerlifter	2.45	1.20	2.15	0.85	1.98	1.22	2.24	1.91
Bodybuilder	1.61	0.94	1.62	1.27	2.02	2.15	1.13	3.33

Discussion

The bench press is a popular exercise used in the muscular development of the upper body and is a component of the powerlifting sport. Despite the extensive use of this exercise in many forms of training regimes, there is a paucity of published research directed toward the mechanical understanding of this movement [7]. Bearing in mind that biomechanics is concerned with the forces that act on the human body and the effects that these forces cause, the first thing to be considered is muscle action. Skeletal muscles are the primary actuator of the movement and are a real biological system designed to produce mechanical force and cause movement. According to various authors [8, 9, 10, 11], an analysis of the internal structure (the level and duration of electrical activity) of the four main muscles involved in flat bench pressing indicates that activity in the descent phase is much smaller than that in the ascent phase. In our study, this was confirmed only by the bodybuilder's results. The aim of this study was to examine whether muscle activity patterns during flat bench pressing were different for the powerlifter and bodybuilder.

The powerlifter and bodybuilder are characterised by an increase in the IEMG activity of the *triceps* if the load increases. Only in the case of the powerlifter does this increase take place at the end of the descent phase. In the case of the bodybuilder, the increase takes place up to the beginning of the ascent phase. With the powerlifter, the *pectoralis major* and *anterior deltoid*, as was the case with the *triceps brachii*, also reached the greatest value of the IEMG at the end of the descent phase, and then the activity decreases. For the bodybuilder, the *anterior deltoid* electrical activity, irrespective of the barbell weight, showed greater activity in the ascent phase and persisted for almost the entire time of the duration of this phase. Based on the current EMG results, it seems that the powerlifter and bodybuilder performed the bench press differently.

Muscle involvement in bench pressing is called barbell kinematics, which is characterised by the graph of acceleration (Fig. 3A and 3B). It definitely changes as the weight of loading increases, but only if the bench pressing ascent phase for the 70% and 80% 1-RM conditions reaches one positive acceleration area (region) and one negative acceleration area (Fig. 3Ba and 3Bb, respectively). In the attempts for the 90% and 100% 1-RM conditions, there are two or more acceleration regions (Fig. 3Bc and 3Bd, respectively). When there are four specific areas, they are named the *acceleration phase*, the *sticking region*, the *maximum strength region*, and the *deceleration phase* [7]. The number of the changes of the acceleration direction (number of +/-) is a measure of the fluidity of the movement [1, 6]. During the *acceleration phase* of the bench press, the bodybuilder showed a large sustained increase in muscular activity from two prime mover muscles. The only exception was the

pectoralis muscle activity at the beginning of the ascent phase when attempting to lift a load of 100% 1-RM, which is difficult to explain.

Acceleration characteristics are reflected in the velocity curve. In the flat bench pressing ascent phase at 70% and 80% of 1-RM, the loads reached one maximum velocity (Fig. 4Ba and 4Bb, respectively); in attempts at 90% 1-RM, there were two maximum velocities (Fig. 4Bc). This decrease in the barbell velocity is called the *sticking point* [12, 13]. Each study on the bench press has identified a sticking point or sticking region (period) at a relatively constant position in the movement, where the lifter experienced apparent difficulty in exerting force against the barbell [7]. Generally, however, the vertical component of the barbell velocity decreases together with increased loading at average and maximum values [14]. With an increasing load, the time of the descent and ascent phase changed, so the rhythm of the flat bench press also changed (Tab. 1).

Conclusions

The results of this study indicated that during the flat bench press, the powerlifter emphasised the activation of the *triceps brachii* muscle. This is particularly evident at the end of the ascent phase in the attempts to lift loads corresponding to 90% and 100% of 1-RM. In the case of the bodybuilder, our study revealed a large participation of the *anterior deltoid* and *pectoralis major*. Another important feature was the external structure of the bench-press exercise performed by the bodybuilder vs. the powerlifter. As the time-history of barbell kinematics (the acceleration-time curve) shows, with increased loading of the barbell, the fluidity of the movement changes (worsens). The bigger the fluidity of the movement, the greater the number of the changes of the acceleration direction (the number of +/-). With the increased loading of the barbell, the rhythm of the flat bench press also changes.

Therefore, the effective improvement of a technique requires trainers to use an individual approach with each athlete. This, however, is significantly more difficult because the internal structure of the movement and the acceleration-time curve are not observable.

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