Effect of Different Pushing Speeds on Bench Press

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Key words
- bench press exercise
- upper body strength training
- electromyography

Abstract

The purpose of this study was to investigate the effect on muscular strength after a 3-week training with the bench-press at a fixed pushing of 80–100% maximal speed (FPS) and self-selected pushing speed (SPS). 20 resistance-trained subjects were divided at random in 2 groups differing only regarding the pushing speed: in the FPS group (n = 10) it was equal to 80–100% of the maximal speed while in the SPS group (n = 10) the pushing speed was self-selected. Both groups were trained twice a week for 3 weeks with a load equal to 85% of 1RM and monitored with the encoder. Before and after the training we measured pushing speed and maximum load. Significant differences between and within the 2 groups were pointed out using a 2-way ANOVA for repeated measures. After 3 weeks a significant improvement was shown especially in the FPS group: the maximum load improved by 10.20% and the maximal speed by 2.22%, while in the SPS group the effect was < 1%. This study shows that a high velocity training is required to increase the muscle strength further in subjects with a long training experience and this is possible by measuring the individual performance speed for each load.

Introduction

Over the years, the research on strength training with the bench press has steadily developed [18,21,25,28,30]. The initial point of this study was the training differentiation according to sex, age and type of sport [1]. Subsequently, other factors were considered, such as the optimal power exercise [2,3]. However, other training parameters have been rarely investigated, including the pushing speed. In order to optimize the load, coaches first determine the repetition maximum (1 RM) [13,17] and subsequently, using Bosco's [5] method, calculate the optimal muscle power to further specialize the subject's training.

In recent researches on bench press, various authors have focused their attention on optimal loads. For example, Iziquierdo et al., identified the 30% optimal training load in weightlifters and handball players, as well as 45% of 1RM for amateur road cyclists and middle-distance runners, pointing out that the highest speed at maximal power is $1\,\mathrm{m{\cdot}s^{-1}}$ [14].

Mayhew et al., instead, suggested optimal loads between 40–50% of 1RM [23], after having conducted a weight training twice a week for 12 weeks with college students. Subsequently Cronin et al. suggested, that, according to the observation of 27 young men (with athletic background but without any weight training experience), the mean and peak power between 50–70% of 1RM [7] were to be found with loads of 30–80% of 1RM. However, Schmidtbleicher et al., observing the effects of strength training on 30 young men with either few repetitions and maximal loads or more repetitions with lower loads, suggested the use of heavy loads (> 80% of 1RM) to induce recruitment of fast-twitch motor units [29].

In fact, other authors, have investigated free weight training that can produce better results than training with machines, which are suitable for guided movements but not for more complex and multi-joint exercises [31]. There are several possible reasons for the superiority of free weight training, in particular the mechanical specificity, which is the appropriate movement pattern, the force application and the velocity of movement resulting in a greater transfer of training [31].

Therefore, resistance exercises making up a training program should include free weight exercises focusing on mechanical specificity (i.e., large muscle mass exercises, appropriate speed, contraction type, etc.). Generally, machines should be used in addition to free weight training, in

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acoordance with the kind of sport [31]. Among the free weight training exercises, the bench press is one of the most popular, allowing full acceleration and high power output for the entire range of motion; [4,32] it is widely used for resistance, strength and power training of the upper body. Unfortunately, no data are currently available about the influence of pushing speed in bench press. Other authors have investigated the force-time ratio finding out that movement speed is one of the main activities of the fast twitch fibers [8,12].

Our hypothesis is that bench press training with high speed movement can significantly influence muscular strength. For this reason, the goal of this study was to compare the effect of different pushing speeds on bench press force and velocity in resistance trained subjects. The training program lasted 3 weeks with 2 sessions per week, using 85% of 1RM as suggested by Schmidtbleicher et al. [29].

Material and Methods

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Subjects

20 resistance-trained subjects were selected for this study after the approval of the University Ethical Committee. All subjects were randomly assigned to one of the 2 groups: first group performed at fixed pushing of the 80–100% maximal speed (FPS, age 42.50±1.87 years, height 1.75±0.06cm, weight 77.08±5.93kg, training experience 18.83±1.87 years). The second group performed self-selected pushing speed (SPS, age 43.83±2.82 years, height 1.74±0.04cm, weight 75.22±4.73kg, training experience 19.33±1.37 years). The subjects were healthy without any muscular, neurological and tendinous injuries and did not report any consumption of drugs. A diet control was designed to eliminate the risk of any major differences between diets in total protein, carbohydrates, saturated and unsaturated fat and hydration in pre and post training. To make the 2 groups homogeneous with regard to their training status, none of the subjects performed any high intensity endurance activity outside their resistance training protocol. After being informed of the procedures, methods, benefits and possible risks involved in the study, each subject read and signed an informed consent form to participate in the study, which was in accordance with the ethical standards of the IJSM [9]

Assessment of upper body strength

The subjects performed a supine (flat) bench press (BP) (Technogym®, Biomedical Line, Gambettola, FC, Italy) using free weights and "touch-and-go" technique. A repetition maximum (1RM) BP test was conducted to determine maximal upper body strength. The test protocol recommended by Kraemer and Fry [19] was adopted as follows: (A) a warm-up including 5–10 repetitions at 40–60% of the estimated 1RM, (B) 1-min rest with light stretching followed by 3–5 repetitions at 60–80% of the estimated 1RM, (C) 3–5 attempts to reach the 1RM with 5-min rest intervals between each new lift. The maximum weight that was successfully lifted was recorded. Each repetition was performed with slow eccentric phase to delete stretch-reflex [24]. After 3 and 5 days, (before and after the training) all subjects were tested in bench press exercise at 85% and 100% of 1RM in the same manner as on the first day in order to ascertain their specific maximal speed. A Linear Encoder (MuscleLab™ BoscoSystem, Ergotest Technology, Langensund, Norway) [5] was connected to the barbell and interfaced with the computer which enabled us to measure the bar position with an 0.001-m accuracy. The system was calibrated before each testing session by counting the total number of pulses produced as the bar was moved through its full vertical range in order to determine the relationship between load and velocity before and after training protocol. During all tests, the subjects were verbally encouraged to attempt the maximum velocity in pushing off the barbell. In each session we recorded the fastest repetition.

EMG analyses

EMG activity of the pectoralis major (PM), biceps brachii (BB), triceps brachii (TB), trapezius muscle (TM) and deltoid muscle (DM) was recorded before the training, during a bench press exercise, in all subjects and in both methods (FPS and SPS) with 85% of 1RM. The bipolar active electrodes (inter-electrode distance 1.2cm) were aligned along the fibres of the muscle under investigation according to the recommendations by SENIAM [11]. Before electrode application, each site was shaved, cleansed with alcohol, and gently abraded, and a small amount of conductive gel was applied to each electrode. An amplifier (gain×600, input impedance 2GΩ, common-mode rejection ratio 100dB, band-pass filter 6-1500Hz; Biochip Grenoble, France) was used. The MuscleLab (BoscoSystem, Ergotest Technology, Langensund, Norway) converted the amplified EMG raw signal to RMS (root mean square) signal total error±0.5%. The EMG signals were synchronized with the biomechanical parameters and were sampled simultaneously. To prevent cable artefact, cables were secured with elastic bands (Vetrap™).

Strength training

Strength training was carried out in the morning and was conducted over 3 weeks with 2 training sessions per week. FPS group performed bench press exercise at 85% of 1RM and they were stopped when the maximum speed decreased by 20% (Range: $0.36–0.45\,m{\cdot}s^{-1}$). The recovery between the sets was fixed to 2 min; the athletes ended the training session when they were not able to sustain the minimal velocity established for that load (85% of 1RM). The SPS group performed the bench press at 85% of 1RM at self-selected speed until forced exhaustion due to trying to do too many repetitions. The recovery was the same as in the FPS group and the athletes ended their training session when they were not able to perform a further repetition.

Statistical analysis

Normality of the distribution for outcome measures was tested using the Kolmogorov-Smirnov test. Statistical evaluation of data was performed using a 2×2 (between-within) analysis of variance for repeated measures ANOVA (pre and post-test) × groups (FPS and SPS) with least-significant difference. The *t*-Student test for independent samples was used to detect any initial difference between groups. The probability level of statistical significance was set at $p \leq 0.05$. Data were analyzed using the SPSS 15.0 (SPSS Inc., Chicago, IL) statistical software package. Descriptive statistics were expressed as mean±SD.

Results

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After the observation of the training effects on both groups, it is now possible to present the following results. Even though there was no difference between groups at baseline conditions for age, height, weight, BMI, training experience, upper body strength

Table 1 Means and standard deviation (± SD) of the maximum load 1 RM (ML), maximal speed 1 RM (MV); before and after training.

Group	Variable	Baseline	Week 3	Percent change (Δ%)
FPS	ML (kg)	99.7 ± 3.08	109.8 ± 4.06	10.20*
	MV ($m{\cdot}s^{-1}$)	0.150 ± 0.07	0.154 ± 0.08	2.22*
SPS	ML (kg)	97.5 ± 1.90	97.7 ± 2.14	0.17
	MV ($m{\cdot}s^{-1}$)	0.146 ± 0.04	0.146 ± 0.09	0.11

FPS = fixed pushing speed,SPS = self-selected speed; "*"P < 0.05 vs. baseline

and load speed, after the training, a significant increase in muscular strength ($p=0.002$) and velocity ($p=0.006$) was registered in the FPS group (▶ **Table 1**), while in SPS group the effect was < 1 % (n. s.). Considering the 2 strategies of training, the FPS group in the starting training program performed 7 ± 0.08 sets of 2.33 ± 0.52 reps with 0.38 ± 0.02 $m{\cdot}s^{-1}$ pushing speed, while at the end of the training, the whole group improved to 9 sets (29.19 % with $p=0.004$) of 3.17 ± 0.75 reps (35.71 % with $p=0.0001$). The pushing speed during the training was 0.39 ± 0.03 $m{\cdot}s^{-1}$ in the FPS group. The SPS group at the start of the training protocol performed 7.98 ± 0.04 sets of 7 ± 0.42 reps with 0.14 ± 0.02 $m{\cdot}s^{-1}$ pushing speed, while at the end of the program they improved to 9 sets (12.73 % with $p=0.0001$) of 8.33 ± 1.03 reps (12.36 % with $p=0.0001$). At a 0.15 ± 0.01 $m{\cdot}s^{-1}$ pushing speed during the training EMG analysis evidenced different pattern of muscle activation in both FPS and SPS exercise strategies (▶ **Fig. 1**). In the FPS method, all muscles tested in a complete movement (eccentric phase – concentric phase – tension phase) [20] showed greater activation compared to that of the SPS method: PM 9.36 % with $p=0.0001$, BB 197.93 % with $p=0.0001$, TB 221 % with $p=0.0001$, TM 0.5 % with $p=0.03$, DM 23.31 % with $p=0.0001$. The eccentric phase (EC), concentric phase (CO) and tension phase (TE) in both methods (SPS vs. FPS) were analyzed separately. The average time spent in the EC of the barbell with 85 % of the 1 RM in SPS was 1.5 s while in FPS it was 2.0 s. CO (pushing the barbell) in SPS was on an average 1.3 s while in FPS it was 0.8 s and TE in SPS method was on an average 1.8 s while in FPS it was 2.1 s (▶ **Fig. 1**). The analysis of EMG showed that the DM is greater in EC, 5.9 % with $p=0.209$, CO 22.8 % with $p=0.0001$, TE 41 % with $p=0.0001$ in FPS and SPS, respectively (▶ **Fig. 1**). The EMG activity of the TM in EC was − 14.16 % with $p=0.0001$, CO − 11.58 % with = 0.0001, TE 26.64 % with $p=0.004$ in FPS and SPS, respectively. EMG activity of the TB muscle in EC was 80 % with $p=0.0001$, CO 202.29 % with $p=0.0001$, TE 403.28 % with $p=0.0001$ in FPS and SPS, respectively (▶ **Fig. 1**). EMG activity of the BB muscle in EC was 90 % with p = 0.03, CO 49.59 % with p = 0.0001 while TE 18.43 % with p = 0.001 in FPS vs. SPS respectively. The EMG activity of the PM in EC was 5.54 % with p = 0.210, CO 7.31 % with p = 0.006 while TE 14.69 % with p = 0.0001 in FPS vs. SPS respectively (▶ **Fig. 1**).

Discussion

This paper shows that the high velocity of movement in the bench press exercise can further increase the muscle strength in resistance-trained subjects because of a greater activation of the upper limb muscles. Although the effect of a training program on strength in adults [10] has been recently studied there are no specific studies on resistance-trained subjects. In this study, training with different velocities demonstrated that the high speed of movement improves muscle strength by 10.20 % in only 3 weeks. It was observed, that in the FPS group, after a 3-week training, the set values increased (35.71 % with $p<0.004$) and the repetitions also increased significantly (29.19 % with $p<0.0001$). At the end of the training program the FPS group had pushed less kg (the total reps at the beginning of the training program were − 72.54 % and at the end of it they were − 62 %, compared to the SPS group). The 85 % of 1 RM is a load for specific training that requires an optimal muscular effort by choosing the speed according to training objectives. We know that by increasing the number of repetitions with the same load, subjects tend to reduce their speed of movement as a result of fatigue. The SPS method allows the athlete to adapt to the load, with disregard of movement speed and a modest increase in muscle strength over time. Certainly this method (SPS) is particularly suitable for beginners, as it enables them to get familiar with the bench press technique and to improve the muscle tendon adaptation to a specific exercise gesture. It is likely that athletes need a long period of functional adaptation and of consolidation of the joint structures before they can shift to a training the object of which is the speed of movement. This procedure on one hand requires a great physical effort, but on the other it leads to higher muscle activation resulting in an adaptation to higher loads, as demonstrated in this study. The evaluation of the maximum load of 1 RM is linked to the individual characteristics of each subject and the choice of training will obviously depend on the athlete's objectives. Since both strategies (SPS and FPS) apply to athletes, we can infer that the amount of energy is the same (▶ **Fig. 2**). In fact, whereas in the FPS method the intensity is high and the number of repetitions is low, in the SPS method the intensity is low and the number of repetitions is high. Therefore speed of movement appears to play a key role. The percentage between 0–40 % of 1 RM might be useful for the athlete to focus on the technical execution of movement; between 40–80 % of 1 RM he should rather concentrate on an extensive training, while between 80–100 % of 1 RM on an intensive training. In FPS training a mechanism of neural adaptation is possible as a consequence of a recruitment of motor units at a high firing frequency [8]. The increase in the motor-unit firing frequency obviously leads to a greater force output [27]. In fact, during the CO, the barbell pushing speed in the FPS method was 63 % higher than in the SPS method while the EMG activity was higher at 59.59 % on the BB, 202.29 % on the TB and 22.80 % on the DM. As demonstrated by other authors [16, 22] these 3 muscles appear to contribute to a large extent as follows: the BB in the starting phase, the DM in the middle phase and the TB in the final phase. The activation of the TM was − 11.58 % lower than in the SPS method. As it was expected, in the EC phase the activity was lowered by the barbell speed of − 14.16 %. In the EC phase of the FPS method the muscular activity was decreased according to the following rates: DM 5.54 %, PM 5.54 %, TB 80 %, DM 5.89 %, TM − 14.16 %. Only the BB increased by 90.18 % in comparison with the SPS method. Furthermore the motor-unit firing frequency exceeds the level that is sufficient to achieve maximum force, so that a further increase in firing frequency contributes to improve the rate of force development (RFD) [27]. RFD is considered an important factor in high power production because time to exert one's force is usually limited in powerful muscle actions. Therefore, increased rate-coding ability as well as motor-unit firing frequency are possible adaptations for high functional performances. In addition to motor-units recruitment and rate coding also a greater synchronization of motor units has been

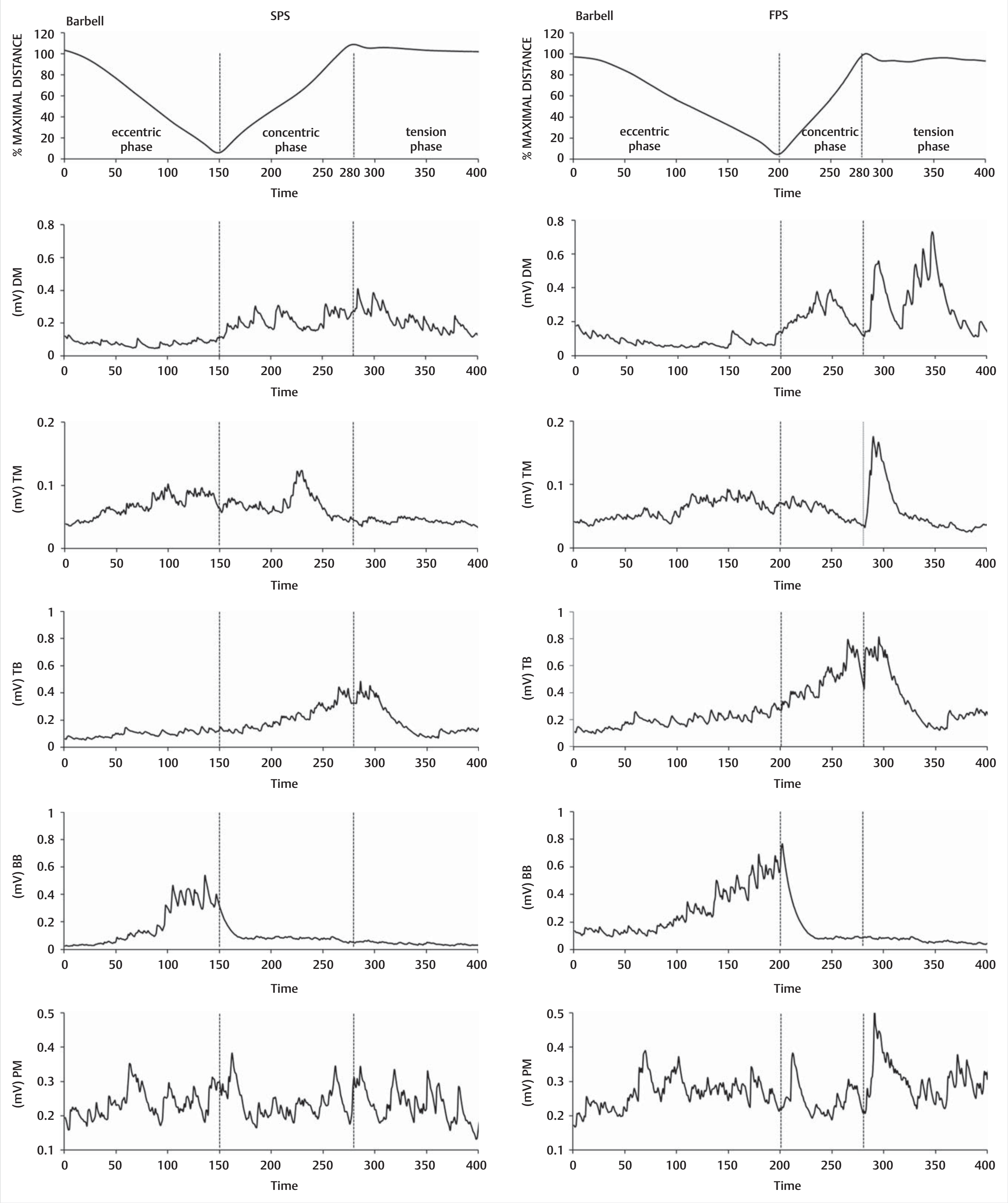

Fig. 1 EMG in FPS vs. SPS strategies. Representative vertical and horizontal Barbell in FPS and SPS strategies synchronized with EMG surface. Rectified and smoothed EMG curves indicate electrical activity of the deltoid muscle (DM), trapezius muscle (TM), triceps brachii (TB), biceps brachii (BB), pectoralis major (PM); all synchronized with barbell; the time is represented at 100 Hz.

proposed to occur as a result of FPS training [6,26]. To sum up, this study compared the effect of 2 methods of resistance training on muscular strength in resistance-trained subjects. The subjects performed the same resistance training exercises, and the only difference between the 2 methods was the speed. Such findings are similar to Kaneko et al.'s results, as the actual movement velocity during the training may play a significant role in determining the velocity and consequently the neuromuscular response to a resistance training [15]. Adaptations induced by the speed of movement are therefore still under investigation by

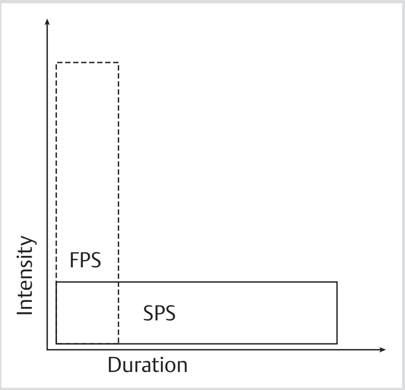

Fig. 2 Relationship between FPS – SPS training methods. Rectangles represent intensity (velocity) vs. duration (time) of the exercise.

the coaches who should readjust training programs according to the new physical properties acquired. Finally, considering the homogeneity of the subjects and their background training in bench press, it is quite amazing that in only 3 weeks there was a 10.20% increase of 1RM. However, further research is required in order to elucidate the effects of the speed modulation on free weight training programs. Moreover, future studies should take into account the cause-effect relationship between performance and EMG activity in order to further improve the performance itself.

In conclusion, this study shows that the speed execution of an exercise leads to a specific muscle recruitment during the whole period. This information is useful as a guideline to work out an optimum training as well as training protocols particularly useful to resistance trained subjects. With reference to the results obtained we consider the encoder useful to evaluate the speed execution of the movement and to check the training. This device is very important during the training, because in a short time either the athlete or the coach receive a “feedback” about the task to perform, as well as about the mistakes which have been made.

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