Rev Andal Med Deporte. 2011;**5(1)**:18-27

Revista Andaluza de
Medicina del Deporte
Rev Andal Med Deporte. 2009;2(4):00-00
www.elsevier.es/ramd

Revisión

ARTÍCULO EN INGLÉS

Maximum power, optimal load and optimal power spectrum for power training in upper-body (bench press): a review

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History of the article:
Received June 9, 2011
Accepted November 17, 2011

Key words:
Bench press.
Maximal power.
Optimal load.
Optimal power spectrum.

ABSTRACT

It is a fact that high performance sport has been characterized in recent years as a more specific training and in which coaches and athletes tend to use exercise and training loads which significantly resemble athletes' real actions during competition.

Principles of individuality and specifity are two aspects which best explain this trend. In that vein, this review analyzes and understands what specialized literature says to reach one of the most popular exercises used in upper-body power development: bench press in its different variants.

Palabras clave:
Press de banca.
Potencia máxima.
Carga óptima.
Rango óptimo de potencia.

RESUMEN

Potencia máxima, potencia óptima y espectro óptimo en el entrenamiento de la potencia del miembro superior (*bench press*): una revisión

Es un hecho que el deporte de alto rendimiento se ha caracterizado durante los últimos años por un entrenamiento cada vez más específico en el que técnicos y deportistas tienden a utilizar ejercicios y cargas de entrenamiento que se asemejan significativamente a las acciones que debe realizar el deportista durante la competición. Los principios de individualidad y especificidad son dos de los aspectos que mejor explican esta tendencia. En esa línea, esta revisión trata de analizar y entender lo que la bibliografía especializada señala con la realización de uno de los ejercicios más populares que se emplean en el desarrollo de la potencia del *upper-body: bench press* en sus diferentes variantes.

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Introduction

Resistance training plays a fundamental role in most of conditioning sports programs[1,2] especially at high levels[3]. It is also known that most of sports actions, especially sport activities involving striking, throwing, jumping or rapid acceleration movements, sustain their performance in specific technical gestures implementation performed at maximum power[4-7].

Power is the work amount produced per unit time or the product of force and velocity (Power= Force x Displacement/Time = Force x Velocity)[7] and maximal power is the highest power level achieved in muscular contractions[8]. Maximal power output in a sport gesture varies with the load, contraction type and technique[9].

Some papers suggest that, maximal power in single muscle fibres and single joint movements is reached approximately at 30% of maximum isometric strength and 30% of maximum isometric shortening velocity[10-16]. For multiple-joint muscle actions, optimal load varies with exercise. It is often said that, for lower body movements, optimal power appears at 0%[17-21] and 55-59% 1RM[22] in jump squat, 60-70% 1RM[23] and 40-65% 1RM[24] in half squat, and 56-78% 1RM[25] in leg press. Optimal load for weightlifting movements, such as clean and/or snatch has been identified at 70-80% 1RM[26]. For upper-body movements, as for example bench press, countermovement bench press and bench press throw, optimal load is achieved between 30% and 70% of 1RM.

Aspects such as movement mechanics[18,19,27-29] age[9], gender[25], fibre type[30], muscle-tendon morphology[31], muscular fatigue[32], training level strength and training experience[33,34] are some parameters that can affect the load percentage at which maximum power is reached in a technical gesture[12,35].

Consequently, the optimal load at which power output is reached is the load intensity in which the perfect combination between velocity and load displacement is produced[16]. This is known as *optimal load* (OL)[7,18,26,35-37]. From a practice point of view, OL and similar power loads where there are no significant differences (optimal power spectrum) are considered as more appropriate loads to develop power at a specific technical gesture[7].

Most of the studies related to OL determination have used three types of exercises (and its variants): total body (e.g. clean, snatch, hang power clean), lower body (e.g. squat, squat jump, leg press, leg extension) and upper body (e.g. bench press, bench pull and curl biceps). OL changes depending on the exercise and muscular group: Olympic lifters (80-100% 1RM) (e.g.[26,38]); lower body (60%) (e.g.[24,39]); upper body (40-70%) (e.g.[13,40]).

In this review, we will focus on the upper-body OL analyzing published works in which bench press, in its different variants, is used. Articles were selected using US National Library of Medicine (PubMed), Scholar Google databases and indexed magazines in Spanish language (Redalyc, Dialnet LILAC y Latindex).

Bench press is one of the most common exercise used in training routines by most of athletes in every sport, being an optimal gesture to increase muscular force of the front of the chest (pectoralis major and pectoralis minor), arms (crural triceps: long, intern and extern portions) and shoulders (medial and anterior deltoids)[41-43].

Therefore, the aim of this paper is to review the optimal load for optimal power development spectrum in bench press (with and without countermovement) in different subjects, thinking of the influence on different kinetic and kinematic variables in maximal power output.

Methodological aspects which can affect muscular power assessment and optimal training load

In order to create force and muscular power assessment studies selection at which capabilities can be trained, we firstly created methodological criteria, which can allow right data interpretation of related studies. We should take into consideration that mostly all investigators make muscular power studies using kinematic systems, which enable muscular parameters assessment in terms of lifted load displacement during an exercise. From an external load on, and once known its displacement and the time to reach it, through specific designed softwares, optimal and mean power are estimated, as well as other kinematic parameters that can be useful to assess muscle or muscle groups mechanical characteristics during performance.

Frequently, there are significant changes in these studies because of the methods used, making difficult the results comparison. The main conflictive highlighted aspects are the few detailed information about morphfunctional sample characteristics, unclear description about exercise execution (e.g. slow or fast countermovement, stopping or not the movement at the end of the eccentric phase, etc.), few information about weight and size values corresponding to body segment displacement (arms, legs or whole body), different load increases used during performance, different exercises used to assess a same body segment (e.g. concentric bench press, bench press with countermovement, or bench press throwing), different measurement instruments and criteria used in the data interpretation (maximal power or mean power), etc. Before starting the bench press revision, we will explain some refinements about the previous mentioned points that, in case not being considered, will affect the revision interpretation.

Power peak and power mean

One of the main data interpretation and bibliography analysis difficulties were peak and mean power values not being clearly indicated. *Maximal power* is defined by Baker and Newton[44], as the maximal power production in the whole range or range of motion/concentric contraction. These authors refer to this value as *peak power (PP)*, referring to a higher instantaneous production in a period of 1/ms without an apparent movement being observed. Some authors define this capability as the moment at which *threshold muscular performance is reached,* corresponding to a maximal mechanical performance that an athlete can produce in a concrete gest or movement[45]. *Mean power (MP)* corresponds to mean values obtained from the sum of all the positive values developed during concentric phase performance divided by the number of data obtained in that gest or range of motion.

Free weigths vs. resistance machine

In overweight training, common materials used are divided into two groups: machines and free-weights. The fact of using one or another will make a change in the final results. The term “machine” usually refers to resistance training devices with cables, pin loaded weight stacks or fixed lever arms. Free-weight encompass dumbbells and plates are typically loaded on to the end of a barbell. Free-weight exercises are performed usually at utility benches or squat racks.

Especially relevant is that barbell free force exercises highly controlled during the whole range motion optimize the gest and prevent from execution possible risks. A detailed analysis of 25 BP movements in

120 experienced weightlifters (candidate master: 30 people; Master of sports of Russia: 70 people; World-class athletes: 20 people) have allowed to establish Ivanovich et al[46] that the barbell displacement, even showing stable parameters in every weightlifter, can present significant individual differences, making changes during the seven phases in which lifting is divided and affecting any body plane (frontal, sagital and transversal).

Using free-weights enhances stabilizing muscles group participation and level activation[47,48]. Contrary, machine exercises cause opposite effect[48-51]. Relative to bench press, it is especially relevant the free-weight effect on shoulders muscles (deltoids). This muscle has a stabilizing function, so that the anterior portion tends to resist a humerus lateral rotation at the same time that medial deltoid tends to resist abduction[48]. This muscle relevancy has also been highlighted by Scheving and Pauly[52] stating that its three portions (anterior, medial and posterior) are activated during this exercise to stabilize the humerus in glenoid cavity and as synergist movement structures.

Anthropometric characteristics

Athletes' anthropometric characteristics are determinant variables in all sports performance and, especially, in those where force is a discriminant capability. Relative to the studied exercise (BP), height and, fundamentally, upper-body (arm and forearm) length are two morphologic parameters which significantly influence in power levels reached during this movement. Generally, individuals with longer arms have greater advantage in BP power developing, rather than those with shorter arms or, even sometimes, higher force levels[53]. Time and displacement to take the barbell to the chest depend on athletes' anthropometric particularities, width of the grip, height of the bridge, barrel displacement, lowering velocity and the barbell weight.

Incidence in the total mechanical system inertia

In order to assess kinematic parameters, the whole mechanical system inertia, must be carefully determined (i.e. mass of the lifted load plus the inertia of the levers and body segments) to be able to precisely calculate the load at which its power training is optimized[54]. In case not making it real, results interpretation force to conclude erroneously, where there is a tendency to underestimate force levels[55] and power[54]. Nelson and Duncan[5] suggested that the gravity effect on the muscular performance should always be taken into consideration in force assessment. According to these authors, not considering these parameters takes, in isokinetic dynamometer (Cybex) assessments, into 4% errors for extensive knee muscles and to 15% for flexive muscles.

Sport gesture technical domain

A right domain technique execution is considered as the key for movement balance and stability, as well as to reach the right force application and power development. Load magnitude will represent the main factor that causes mechanical alterations in force exercises. Specifically, it is easy to prove how by making a PB at high loads (#>80% 1RM) technical execution is seriously compromised, especially when training level and experience are low. Major changes are observed in load control and range motions. The movement magnitude in a BP decreases at higher loads because of a higher scapula protraction[56].

Individuals' training level

Power production depends on the subjects' maximal strength level, which frequently is determined by their training level. So, it doesn't seem strange to conclude that, the more trained the subjects are, the higher levels in force and PP will have.

Assessment methods and data collection

It is a fact that every instrument presents a different reliability degree, wich affect directly to published results. This mechanism consisted of an optic encoder with a digital recorder connected (displacement error below 0.16%; 0.02% of time circuit error). Cronin et al[57] used a lineal position transductor (Unimeasure, Corvallis, OR), connected to a Smith Press machine, which would allow a velocity and movement variation assessment at a sampling frequency of 200 Hz (0.01 cm of precision). Siegel et al[29] used a chronoscopic light mechanism (model 63501 IR, Lafayette Instrument Company, Lafayette, IN) connected to a time mechanism (CLOCK Model 54050, Lafayette). On its part, Jandacka and Vaverka[58] used a rotational encoder at a 100 Hz sampling frequency (FitroDyne Premium - University of Komensky, Bratislava).

Optimal load, mean power and peak power in bench press

The following analysis is divided into PB_{CC} and PB_{SSC} movements from BT in its different variants (BT_{CC}, BT_{SSC} and BT). In each case, the following parameters are assessed: OL, PLS and power (PP and PM).

Concentric bench press and countermovement bench press

In order to make the OL analysis in PB_{CC} and PB_{SSC}, thirteen studies have been included. Nine of these examined BP_{CC}, three studied BP_{SSC} and the other two studied both movements (BC_{PP} + BP_{SSC}). Except in the study by Jandacka and Vaverka[58] and Naclerio and García[53] in which women were included in the sample (n=52), the rest of the evaluated subjects were men (n=363; men: 311; women: 52) of different level performing and force training experience. One group was formed by young elderly (≈40 years) and elderly (≈65 years)[59] and the rest were young adults (≈20-25 years), in which practitioners from different sports modalities were included (weightlifting, bodybuilding, basketball, handball, cyclists, volleyball, sprinters, middle distance runners and sailors)[2,24,60-62]. The rest of the sample is formed by moderate active young health men volunteered[29,53,57,58,63-65] (table 1).

As expected, most active subjects, especially the ones who practiced sports which required force conditions (powerlifting, weightlifting) or power (sprint), presented higher force levels, especially when results were expressed in relative values (1RM/BW) or were assessed according to their body weight and age (advanced or intermediate level). The strongest ones were powerlifting practitioners[60]. In addition, sample subjects' high strength levels were highlighted in the study by Pearson et al (2009), which were elite-level sailors from the Emirates Team New Zealand America's Cup syndicate. Weakest subjects (novice or untrained) were the endurance modalities practitioners (cyclists and runners), subjects who didn't regularly practice sport and the oldest ones[59].

Table 1
Studies analyzing concentric bench press movement (BP_{cc}) and with countermovement (BP_{ss}). Sample characteristics are identified, age, body weight, maximal force (1-RM), relative force (RM/BW) and assessment instruments

Bench press with countermovement (BP_{cc}) and without it (BP_{ss})

Article	Sample	Age (years)	BW (kg)	Performance 1-RM - RM/BW/L	MV
Mayhew et al[63] BP_{SSC}	Male: 24 College Stud FA/TE (Smith Rack)	20.1±1.5	80.6±12.5	93.9±28.3/1.17 (I)	Optic Digital Encoder
Izquierdo et al[59] BP_{CC}	G_{40}: 26 M-FA G_{65}: 21 M-FA	42.0±2.9 65.0±4.1	84.0±9.6 78.0±9.3	59.5±2.0/0.71 (N) 47.0±2.4/0.60 (I)	LPT
Cronin et al[57] BP_{CC}	Male: 27 EE (U_{6M})	21.9±3.1	89.0±12.5	RM_L: 72.0±6.6/0.81 (N) RM_H: 100.9±7.2/1.13 (I)	LPT
Cronin et al[64] BP_{CC} + BP_{SSC}	Male: 27 EE (U_{6M})	21.9±3.1	89.0±2.5	86.3±13.7/0.97 (N)	LPT
Izquierdo et al[24]	Male: 70				
BP_{CC}	WL: 11	22.6±3.0	80.6±10.0	87.3±1.0/1.08 (I)	
	HP: 19	22.4±6.0	83.1±10.0	77.2±1.0/0.93 (I)	LPT
	RR: 18	21.4±1.0	67.0±15.0	53.9±7.0/0.80 (N)	ER
	MD: 10	23.1±5.0	66.4±4.0	53.9±7.0/0.81 (N)	
	CG: 12	20.6±1.0	71.9±8.0	53.9±7.0/0.75 (UT)	
Siegel et al[29] BP_{SSC}	Male: 25 Student TE	23.0±4.0	89.0±30.0	79.3±14.1/0.89 (N)	CTL+TD
Naclerio and García[53] BP_{CC}	UUTS: 37 Male: 33	22.0±2.1	U	76.0±10.2 (-)	LPT
Naclerio et al[60] BP_{CC}	Male: 9 PL Female: 4	18.0-39.0	99.3±15.9	137.0±34.5/1.38 (A)	LPT
Asçi and Açikada[62]	Male: 56				
BP_{CC}	SP: 13	24.1±6.1	72.5±7.1	82.3±18.4/1.14 (I)	LPT
	BP: 16	23.3±3.5	84.3±10.3	79.2±14.1/0.94 (N)	
	HP: 16	22.6±4.9	86.1±8.9	77.2±12.8/0.90 (N)	
	VP: 5	23.2±3.8	81.6±6.7	75.5±12.2/0.93 (N)	
	BB: 6	24.2±3.1	77.5±7.2	86.3±10.8/1.11 (I)	
Marqués et al[61] BP_{CC}	Male: 14 HP	22.3±3.7	82.5±12.2	68.9±10.1/0.84	Rotary Encoder
Jandacka and Vaverka[58] BP_{SSC}	Male: 55 Female: 48 PES	21.8±1.5 21.1±1.2	75.2±8.7 58.7±6.6	68.99±17.3/0.92 (N) 31.50±6.2/0.54 (N)	LPT FitroDyne
Pearson et al[2] BP_{CC}	Male:12 FA-Sailors	33.95±3.5	97.8±12.5	119.7±23.9/1.22 (I)	LPT
Sánchez et al[65] BP_{CC}	Male: 100	25.1±5.0	79.4±8.3	98.7±12.5/1.24 (I)	LPT

A: advance level; BB: bodybuilders; BP: basketball players; BPCC: concentric bench press; BPSSC: bench press stretch-shorten cycle; BW: body weight; CG: control group; CTL+TD: chronoscopic timing lights connected to a timing device; EE: experienced subjects; F: female; FA: physically active; G: group; HP: handball players; I: Intermediate level: L: level; LPT: lineal position transducer; M: men; MD: middle distance runner; MV: valuation method; N: novice level; PES: physical education students; PL: powerlifters; RE: rotary encoder; RM: repetition maximum; RMH: strongest subjects; RML: weaker subjects; RR: road race; SP: sprinters; SP: sprinters; U: values not identified; U6M: untrained during the last 6 months; UT: untrained level; UUTS: not strength-trained university; VP: volleyball players.

It is well known that there is a strong relationship between maximal strength (1RM) and maximal power production[20,39,66-75]. However, the strongest relationship between them occurs in heavier loading intensity[76]. The reason for this is the fact that strongest subjects usually possess favorable neuromuscular characteristics[15,77]. Also, it should be taken into consideration that strongest subjects usually present higher muscular development with a high cross-sectional area[78-81]. In case of the most explosive athletes, hypertrophy mainly corresponds to fibers type II[81-83].

Optimal power training zones range between 30 and 70% of 1RM, with values always close to 50% for OL. However, OL does not seem to show a stable behavior in all analyzed studies, influenced by age, force level or training type of the subject. We can observe in the study by Izquierdo et al[24] how strongest subjects present lower OL, while in the ones by Asçi and Açikada[62] and Cronin et al[57], higher OL values correspond to bodybuilders (63%) or to subjects with a higher RM (60%) level. To our understanding, these differences have turned into a discussion topic between sports coaches, at the time of selecting the most efficient training loads to develop muscular power.

Some studies[39,84,85] suggest that optimal load occur at higher loads in individuals with significantly greater maximal strength. We find the most highlighted case in the study by Propawski[82], who proposes loads of approximately 70% 1RM for strongest subjects and 50% 1RM for weakest. However, Baker[22] suggest that stronger athletes reach their maximal power output at lower loading rates in comparison to weaker

Table 2
Performance factors in concentric bench press movement (BPcc) and with countermovement (BPssc). Optimal load, optimal power espectrum, peak power and mean power values are shown.

Article	OL % - 1RM	OPS % - 1RM	PP - Watts (M-SD)	PM - Watts (M-SD)
Mayhew et al[63] BP_{SSC}	40% Pre 40% Post	40-60% Pre 40-60% Pos	437.0±138.6 474.2±121.7	U
Izquierdo et al[23] BP_{CC}	G_{40}: 45% G_{65}: 30%	30-45% (AG)	U	G_{40}: 293.0±11.0
Cronin et al[57] BP_{CC} + BP_{SSC}	RM_L: 60% RM_H: 40% RM_L: 40% PP RM_L: 60% PM RM_H: 60% PP RM_H: 60% PM	40-60% 40-60% PP 40-60% PM	BP_{CC} RM_L: 501.8±55.3 RM_H: 572.7±79.8 BP_{SSC} RM_L: 444.9±66.5 RM_H: 556.0±80.9	BP_{CC} RM_L: 237.6±29.0 RM_H: 314.6±62.0 BP_{SSC} RM_L: 243.8±52.1 RM_H: 353.1±66.3
Cronin et al[64] BP_{CC} + BP_{SSC}	50% PP: 50% MP: 70%	50-70% PP: 50-70% MP: 50-70%	BP_{CC}≈555.0^{DG} BP_{SSC}≈560.0^{DG}	BP_{CC}≈275.0^{DG} BP_{SSC}≈325.0^{DG}
Izquierdo et al[24] BP_{CC}	WL: 30% HP: 30% RR: 45% MD: 45% CG: 45%	30-45% 30-45% 45-60% 45-60% 30-60%	U	486.0±10.0 468.0±76.0 272.0±52.0 269.0±45.0 266.0±30.0
Siegel et al[29] BP_{SSC}	PP: 50%	PP: 40-60%	U	≈500.0
Naclerio and García[53] BP_{CC}	MP: 53.3±10.7% PP: 47.1±10.7%	U	627.0±150.7	371.4±93.7
Naclerio et al[60] BP_{CC}	45.5±10.6%	U	U	619.2±150.3
Asçi and Açikada[62] BP_{CC}	SP: 52±12% BP: 50±14% HP: 58±16% VP: 54±12% BB: 63±16%	50-63%	U	SP: 227.0±115.0 BP: 232.0±201.0 HP: 190.0±98.0 VP: 300.0±307.0 BB: 221.0±96.0
Marques et al[61] BP_{CC}	PP: 38% MP: 52%	PP: 38-52% MP: 38-52%	≈820.0	≈450.0
Jandacka and Vaverka[58] BP_{SSC}	M: 56±9% F: 63±8%	50-70% 50-70%	279.4±73.5 109.2±73.5	U
Pearson et al[2] BP_{CC}	50%	U	≈600.0	306.0±75.0
Sánchez et al[65] BP_{CC}	54.2%	40-65%	453.0±69.0	938.0±148.0

BB: bodybuilders; BP: basketball players; DG: graphic values; HP: handball players; OL: maximal power percentage; OPS: optimal power spectrum; PP: peak power; PM: mean power; RM: maximal repetition; RM_H: stronger subjects; RM_L: weaker subjects group; SP: sprinters; U: not shown; W: watts; $M_{UP.}$ male upward phase; $M_{AUP.}$ male acceleration phase.

athletes independently analyzed gesture. Other authors suggest that OL could always be the same independently of the subjects' force level[20]. From the study by Izquierdo et al[23] we can also deduce that OL depends on the age, diminishing its value as it increases.

As shown in table 2, from the study by Izquierdo et al23, higher [power values...] higher power values also correspond to strongest subjects, who present close values to 600 watts or more in PP and 300 watts in PM. Specifically, force velocity sports modalities athletes in which higher loads are moved (weightlifting), or those athletes to who add to the explosive gests a high height (basketball and volleyball players), are the ones who reach higher power levels.

Bodybuilders' low power level is highlighted in the study by Asçi and Açikada[62] (≈220W), which can be explained by the type of training, where work volume is significantly higher than the quality and execution high velocity adaptations in which hypertrophy has a general character and the same influence on slow and fast fibers.

Force importance and, more concrete, the way this is manifested, is especially relevant to power development. This capability is directly proportional to the peak acceleration and the mass of the object (a=F/m). Peak barbell acceleration is decreased as the intensity level is increased mainly being affected at the 2nd pull phase[86]. We should take into consideration that, at constant resistance, non-ballistic movement involves two phases (acceleration and deceleration). The middle portion of the ascent is composed by the first deceleration phase and is defined as the effort portion where the applied force falls below the weight of load. The second acceleration phase, or the maximum strength region, is defined as the period where the applied force becomes greater than the load for the second period of time[87]. Elliot et al[88], assessing the bench press, demonstrated that the deceleration phase corresponds to 23% of the last barbell range motion, when work at high loads is produced (1RM), increasing its value until 52% of the total displacement when loads were reduced to the 80%. However, we should take into consideration that, when loads are especially high, (80-100% 1RM), instead of two phases, force presents four phases or regions (acceleration, sticking, maximum strength and deceleration)[51,88,89].

Sato et al[86], suggest that peak barbell acceleration does not change from 50 to 80% of 1RM in elite and experienced weightlifters, indicating that the force production becomes greater while the barbell mass is increased and the peak barbell acceleration remains relatively constant. Peak barbell acceleration is significantly decreased at increases ranging from 80 to 85% of 1RM. The results demonstrated that the force affecting barbell acceleration at the 2nd pull phase reaches near maximal level around 85% of 1RM.

Duration of the acceleration, during concentric phase, decrease with load. For example, acceleration phase change of 63.8% of the duration of the concentric phase, to 82.9 for 30 and 80% 1RM respectively[56]. However, Sato et al[86] found that the peak barbell acceleration showed no changes from 50-80% 1RM among elite and experienced weightlifters, indicating that barbell acceleration remains relatively constant. Force affecting barbell acceleration at the 2nd pull phase reaches near maximal level around 85% 1RM. In other words, force production remains relatively the same while the peak acceleration decreases and the mass of the barbell increases. These showed that roughly 80% 1RM is the threshold for the elite level weightlifters to be able to maintain the peak barbell acceleration.

As previously mentioned, the way force is developed and applied to movement is the key of the barbell acceleration. In case peak force appears prematurely during concentric phase, a force decrease will occur during the last period of the range motion or, contrary, if velocity peak delays and acceleration phase is too long, end of a greater decline in force and a drastic deceleration at the concentric phase will occur[87]. Barbell acceleration magnitude determines its velocity at the different displacement points. Its mean and maximum values will vary depending on the work load, decreasing velocity as the load is increased. González-Badillo and Sánchez-Medina[90] found a high relationship between mean velocity and relative load (1RM-%) that allows us to use one to estimate the OL with great precision. Also, these authors suggest that mean velocities attained with each 1RM (%) can differ very slightly due to differences in velocity at 1RM. During concentric phase an increase in mean velocity is associated with a decrease in concentric phase duration and the magnitude of the load lifted. A 100% increase in mean velocity necessitated a 37.5% load reduction, whereas a 50% reduction in load was required to attain an equivalent increase in the peak velocity[56].

In most frequently movements used for power training (e.g. bench press; squat, clean, etc.), we notice how barbell velocity decreases in the last part of the movement. This is probably due to a decrease in agonists muscle activation and possible increase in antagonist muscles activity, in order to stop the load at the end of the range of motion[4]. In ballistic actions (eg. jump squat and bench press throw), a continued acceleration is observed throughout the range of motion, concentric velocity, force, power and muscle activation. These factors are higher during a ballistic movement in comparison to a similar traditional resistance training exercise[4,16].

A key in force development and muscular power is the kind of movement during the exercise execution. Countermovement actions take place to increase gest efficiency and enhance muscle mechanical answer. This hypothesis is true for PM in both studies[57,64] including both movements (BP_{CC} and BP_{SSC}), as well as for PP[58,64], but not being the same in the study by Cronin et al[57], where peak power across the total concentric phase was not affected by rebound action. These authors explained that rebound movement effect is produced to cause a shift phase in the power-time signal onto the left, peak power remaining unaffected in temporal terms. Consequently, these authors suggested that greater peak power would seem like a maximal strength function rather than individual's ability to utilize the SSC.

An eccentric muscle action stimulates the stretch reflex and builds up elastic energy allowing, mainly, force and power levels improvement during the subsequent concentric action[71,91-93]. Mechanical source SSC bases were initially established by Cavagna et al[94] and have been analyzed by numerous subsequent studies aimed at analyzing its manifestation and effects magnitude. Potential SSC benefits are caused by energy stored in the elastic components (tendons and actin-myosin complex) utilization, reutilization and parallel (aponeurosis) of the musculotendinous system[94-101], spinal reflex[98-100] and long latency responses[101].

Elastic-reflex enhancement may be reflected in higher increases at 10-15% in power output[54,57,97,102]. However, as seen in this review, SSC benefits vary considerably in each individual[103,104], especially when execution deficiencies differences are shown and force levels are low. Some authors[64,99] suggested that a part of countermovement efficiency lost could be due to two phenomena: elastic energy loss caused by slow decreases and prolonged coupling phases, or by muscles inability to generate force at high muscle shortening velocities.

Peak velocity occurs later whereby the SSC effect has diminished[13,64]. Some authors suggested that the elastic-reflex use only maximizes concentric movement initial part[13,57,76,105-107]. Cronin et al[57] observed how enhancement is manifested in the first 200 ms of the concentric phase[13,57], linking the efficiency in the initial phase of the thrust stage with the athlete's maximal force. Bosco et al[99] suggested that during elongation phase above 500 ms, longer coupling is produced; causing an elastic energy decrease that could be stored in the muscle during the eccentric phase. However, Schmidtbleicher[76], doesn't fully accept this announcement, suggesting that if maximal strength is the main power performance factor, especially at the beginning of the push phase, everything will be conditioned by the external load used, diminishing their influence with decreasing load.

In countermovement muscle actions, peak acceleration and peak force have been shown to increase intensively. To this, it is necessary to have enough force to reduce the eccentric velocity of the load to zero prior to begin the concentric action. The change in momentum is directly proportional to the change in velocity and the mass of the load, increasing at fast and short eccentric phases and decreasing otherwise. This change in momentum is also proportional to the force which is causing such a change, and the duration over which the changes take place. The sum of external force in eccentric phase, supposedly, allows higher accelerations during the initial portion of the concentric phase. Perhaps, potential benefits depend on the ability to use the force increase quickly, via recruitment of a high number of motor units and a quickly elastic energy recovery.

Bench press throwing: concentric bench press and stretch-shorten cycle

In this section, six studies have been analyzed[13,17,22,34,40,64], of which three study only concentric bench press throw (BT_{CC}) and the other three assessed the same movement, adding the stretch-shorten cycle bench press (BT_{CC}+BT_{SSC}) (table 3). In all of them, young adults (230 males), were used as sample, except in the study by Cronin et al[64], in which the sample presented a low performance (Novice level), the other five studies, assessed athletes with good force levels (Intermediate or Advanced level).

Exercises with barbell release, as the ones analyzed in this paragraph, are called *dynamic*[36], *explosive*[108] or *ballistic exercises*[4]. In any exercise, barbell throwing incorporation pretends to get closer to a competition behavior. This way, we can adapt the motor pattern used in competition, as well as.

The used motor pattern to real athlete's needs during performance. Also, it is pretended to eliminate, or minimize the characteristic deceleration phase at the end of the sports gest in which the bar (or implement) is not released during the last displacement part[4,87].

These reasons motivate athletes and coaches to train this kind of movement, especially when the training goal is power development. In the case of BP, its use makes significant changes in kinetic and kinematic traditional movements[109], with or without countermovement, where it is important that the barbell is controlled during the whole range of motion. We find the most important differences in concentric phase where a shorter time period is reached, as well as higher peaks and average velocities, which later will be traduced into average force enhancements, MP and PP in traditional movements[4].

We can easily observe that the barbell velocity changes at any load intensity. Newton et al[4] quantified these increases at 27.3% of mean velocity at 45% 1RM. This velocity will go on increasing or will keep maintained while the athlete keeps the barbell control. The point at which the load loses contact with the athlete, leads to any muscular force and therefore any change in velocity is not possible except for the gravity force causes, which is not included in any kinematic or kinetic calculation[87].

Commonly, most of every overweighed training exercise, forces the athlete to stop a substantial portion of the range and control the movement to guarantee the structural muscular integrity, as well as the gestural involved joints (e.g. in BP we talk about elbow joint). This supposes that, during the barbell range, there is a decelerated gest phase prior to achieving zero velocity[4,88,108]. This displacement part is accompanied by a muscular activity reduction, manifested in the agonist muscles electromyography activity. Deceleration results from shortening agonist activation and greater antagonist co-activation, especially at low loads performance[4].

In these circumstances, load determinates the acceleration range and stops at concentric movement phase. Cronin et al[64] suggested that higher peak velocities will be reached later when PT is being performed, rather than when classic PB is performed. However, this phase will be determined by the load to move. Some studies demonstrated that during bench press with a light load (45% 1RM) deceleration phase was shorter (≈40% of concentric time)[4] compared to heavy loads of 80% of 1RM (50% of concentric time)[88]. Consequently, subjects with a higher force level will be in advantage during ballistic movements, when capability to develop force in a few period of time is high.

Results will turn into faster and more powerful gest. In assessed studies, we observe that except in the sample studied by Cronin et al[64], capability to apply force and power development is higher in mostly all the subjects (PP: 600-1,000 watts), than the one we see in traditional PB, where the barbell is not released (table 4). In the analyzed studies, maximal power was found in diverse power values. This way, while in the studies by Newton et al[13] (OL: 15-30%) or Bevan et al[17] (OL: 30%) optimal power was obtained at low work intensities, in studies by Baker[22,34,40] and Cronin et al[64] OL was reached at loads between 50-60%. No significant differences were found between OL in PB_{CC} and PB_{SSC}. Optimal power spectrum was always detected at nearly or slightly higher OL intensities.

As noted above, in barrel released movements, force changes during the course, as it depends on the load (RM). Thus, at high loads, an initial peak force in the early stage of the movement is produced and then it decreases near the end of gesture. Different is the behavior at lower loads, where maximal force is produced at the beginning and then gradually decreased until the end of the movement.

Table 3
Performance factors in concentric bench press movement (BPcc) and with countermovement (BPssc). Optimal load, optimal power espectrum, peak power and mean power values are shown

Concentric Bench Press Throw (BT_{CC}) SST Bench Press (BT_{SSC})					
Author	**Sample**	**Age (years)**	**BW (Kg)**	**1-RM (Kg)**	**MV**
Newton et al[13] BT_{CC}-BT_{SSC}	17 - Men TE (T_{6M})	20.6±1.9	83.7±8.2	104.0±16/1.24 (I)	ER
Cronin et al[64] BT_{CC}-BT_{SSC}	27 - Men TE (U_{6M})	21.9±3.1	89.0±12.5	86.3±13.7/0.97 (N)	LPT (PPS)
Baker[34]	Male: 49				
BT_{CC}	NRL: 22	24.3±3.7	93.4±9.6	134.8±15.2/1.44 (A)	LPT
	SRL: 27	18.1±1.1	91.1±9.8	111.0±15.3/1.22 (I)	(PPS)
Baker[40]	Male: 59				
BT_{CC}	NL: 19	NL: 25.1±3.4	NL: 94.8±10.0	NL: 140.1±14.0/1.48 (A)	LPT
	SL: 23	SL: 19.7±2.0	SL: 91.8±7.0	SL: 121.1±13.0/1.32 (I)	(PPS)
	SRL: 17	SRL:17.6±0.9	SRL: 91.8±10.0	SRL: 108.7±16.0/1.18 (I)	
Baker et al[22] BT_{CC}	Male: 31 Football	22.2±3.5	92.0±11.1	129.7±14.3/1.41 (I)	LPT (PPS)
Bevan et al[17] BT_{CC}-BT_{SSC}	Male: 47 Rugby	25.5±4.8	101.0±12.8	124.0±19.0 - 1.22 (I)	BMS LPT

A: advance level; BT_{CC}: concentric bench press throwing; BT_{SSC}: stretch-shorten cycle bench press throwing; BW: body weight; ER: encoder rotatory; I: Intermediate level: LPT: lineal position transducer; M: men; MV: valuation method; N: novice level; NRL: national rugby league; PES: physical education students; PPS: plyometric power system; RM: maximal repetition; RM_H: strongest subjects; RM_L: weaker subjects; SRL: college-aged rugby players; U_{6M}: untrained the last 6 months; U: values not identified.

Table 4
Performance factors influence in concentric Bench Press Throw movement (BP_{CC}) and Bench Press Throw with countermovement (BP_{SSC}). Optimal load, training optimal range and mean and peak power values are shown

Bench Press Throw Concentric (BT_{CC})				
Author	**OL % - 1RM**	**OPS % - 1RM**	**PP Watts (M/SD)**	**MP Watts (M/SD)**
Newton et al[13]	PP_{CC}: 15%	PP_{CC}: 15-30%	≈1.000.0^{DG}	≈400^{DG}
BT_{CC}-BT_{SSC}	MP_{CC}: 30%	MP_{CC}: 30-45%	≈1.050.0^{DG}	563.0±104.0
	PP_{SSC}: 15%	PP_{SSC}: 15-30%		
	MP_{SSC}: 30%	MP_{SSC}: 30-45%		
Cronin et al[64]	PP_{CC}: 50%	PP_{CC}: 40-60%	≈620^{DG}	≈290^{DG}
BT_{CC}-BT_{SSC}	MP_{CC}: 60%	MP_{CC}: 50-70%		
	PP_{SSC}: 50%	PP_{SSC}: 40-60%	≈625^{DG}	≈340^{DG}
	MP_{SSC}: 60%	MP_{SC}: 50-70%		
Baker[34]	NRL: 51.1±5.3%	44.4-59.2%	U	610±79
BT_{CC}	SRL: 54.9±5.6	45.1-63.1%		515±78
Baker[40]	NL: 50%	NL: ≈40-60%	U	NL: 635±87
BT_{CC}	SL: 50%	SL: ≈40-60%		SL: 561±57
	SRL: 55%	SRL: ≈40-60%		SRL: 499±81
Baker et al[22]	54.9±5.3%	50-60%	U	588.0±95.0
BT_{CC}				
Bevan et al[17]	30%	30-50%	U	
BT_{CC}-BT_{SSC}	30%	20-60%	873.0±24.2	873.0±23.7

DG: graphic values; MP: mean power; OL: optimal power load percentage; OPS: optimal power spectrum; PP: peak power; RM: maximal repetition; RMH: strongest subjects group; RML: less strong subjects; TE: training experience; U: not shown; W: watts.

This leads to changes in size, shape and timing in the acceleration phases. In PB, the acceleration phase is larger than in a single concentric movement. Along these lines, Newton et al[4] found that for ballistic actions, working with a load of 45% 1RM (bench press), acceleration is generated during 96% of the course, compared to 60% of concentric actions. This represents an increase of ≈36 of peak velocity and significant changes in peak power[4]. As in traditional BP, when a countermovement is included in BT, MP is favored (with differences ranging between 15-30%), although it's not the same situation as in PP.

Conclusions and practical implications

The results in this review show how upper-body power training with bench press exercise passes through the optimal load and optimal power spectrum, allowing the maximal power output evaluation. Parameters such as age, training level and sport specialization marked differences in the optimal load and optimal power spectrum value. In addition, with the aim of optimizing bench press technical variants (BP_{CC}, BP_{SSC} or BT) it is necessary that, previously, have enough force levels and an appropriate execution technique.

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