THE ROLE OF RATE OF FORCE DEVELOPMENT IN BENCH PRESS PERFORMANCE

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INTRODUCTION

The barbell bench press is one of the most popular and commonly performed strength training exercises, often serving as a cornerstone movement in resistance training programs for athletic and non-athletic active populations alike. The exercise is heavily immersed in gym culture and often serves as a measuring stick of an individual's strength and bravado.

The barbell bench press is a compound, multiarticular movement which represents one of the three event lifts within the sport of powerlifting (35). The barbell bench press can be used to assess fitness qualities, specifically muscular endurance, among American football players (26), National Basketball Association (NBA) prospects (22), law enforcement recruits and training academy cadets (23), military personnel (43), and maximal or limit strength among powerlifters (35). Among tactical personnel, one-repetition maximum (1RM) bench press performance, along with 1RM pull-up performance, has been shown to be an indicator of loaded march performance (33).

Physique athletes, including bodybuilders, oftentimes laud the barbell bench press as a "mass builder" because it permits heavier external loading, attendant mechanical tension, and resultant muscle damage and metabolic stress, which collectively stimulate muscular hypertrophy when recovery and nutrition are optimal (21,24). Also, the bench press affords athletes the opportunity to alter their hand placement, including grip width and grip type (e.g., pronated or supinated), which in turn, enables the athlete to target different muscle groups or regionalize stress to individual muscles and their specific attachments. For instance, surface electromyographical (sEMG) analysis demonstrated distinct differences in muscular activation patterns across narrow (biacromial or shoulder width), medium, and wide grip (with hands spaced up to 81 cm apart) hand placements (38). Early sEMG analysis illustrated greater activation among the clavicular aspect of the pectoralis major and the long head of the triceps brachii during barbell bench presses performed with biacromial hand placement (3). These findings were corroborated by more recent analyses showing greater activation of the clavicular aspect of the pectoralis major and triceps brachii (2), which could also be influenced by bench angle (21).

Despite these findings, many athletes employ wide grips to reduce the range of motion to improve performance on the barbell bench press. Though a wider grip activates both clavicular and sternal heads of the pectoralis major, it also increases injury risk (24). Acknowledging that this strategy is not optimal, nor sustainable, especially when performing the barbell bench press with appreciable external loading, it is imperative that sound methodologies aimed at improving performance on the bench press are deployed. Determinants of strength performance and measures to enhance rate of force development critical to bench press performance will be elucidated for future application.

BACKGROUND

Performance on the bench press is governed by a constellation of attributes including upper limb anthropometry, torso girth, body composition, and fitness qualities such as strength (35). Strength is defined as the capacity to exert force at any given velocity (10). Determinants of strength performance include physiological cross-sectional area (PCSA), muscle length, pre-stretch, and myosin heavy chain isoform content, categorized as Type I, Type IIa, and Type IIx muscle fiber types (27). Human muscle can produce tensile forces approximating 30 N/cm^2 (27). An increase in this area, or PCSA, expressed as cm^2 in the form of increased fibers in series and parallel will influence force potential. Muscle length can also influence force production. Greater lengths under active tension as exemplified by actin and myosin no longer overlapping and under passive tension as typified by stretching myofascial tissue slightly beyond (or approximately 120% of) its resting length are optimal for force production (29). Pre-stretching of a muscle immediately preceding concentric muscle action can reduce the latency period from the resting length of the muscle eventuating contraction. During pre-stretching, the slack in the connective tissue is reduced and elastic energy from non-contractile elements is harnessed and summarily dispelled.

Muscle fibers are classified into three types according to their fatiguability and tension development characteristics: Type I muscle fibers, or slow-twitch oxidative, are the most fatigue resistant, but produce the least amount of tension; Type IIa, or fast-twitch oxidative-glycolytic, can produce great amounts of tension and are moderately fatigue resistant; and Type IIb, or fast-twitch glycolytic, are the least fatigue resistant, but produce the greatest amount of force. Fiber type distributions are genetically fixed; however, the versatile Type IIa fibers can take on characteristics of either Type I or Type IIb fibers, depending on their adaptations to aerobic endurance training or resistance training, respectively. Additionally, fatigue can also impact force production as muscular tension declines via repeated activation and contractions as the demand for adenosine triphosphate (ATP) eclipses intramuscular supply during sustained bouts of exertion, inhibiting local muscular performance and attendant force production. Reductions in peak force have been observed in fatigued states that are typified by a decline in the force per cross bridge and number of cross bridges noted in high-force states (8); also noted is a reduced amplitude of $Ca2+$ transient that impede cross-bridge cycling that facilitates faster contraction speeds (8).

Rate of force development (RFD), or the rate at which force is produced, is a measurement of explosive strength (32), and may be a better indicator of athletic performance and functional daily tasks than maximal voluntary contraction (MVC) strength (25). RFD is sensitive to detect aberrations or changes in neuromuscular performance and is mediated by numerous physiological mechanisms, which can be modulated through specific resistance training modalities (1,32).

Neural determinants of RFD, such as motor unit recruitment and motor neuron discharge frequency influence the magnitude and speed of muscular contractions. Resistance training confers greater motor unit recruitment and synchronization as well as increased discharge frequency, which ranges from 60 – 120 Hz at baseline among untrained subjects to beyond 200 Hz among trained individuals (6,25). Increased discharge frequency resulted in the greater contributions of higher threshold motor units, postulating the phenomenon of selective recruitment, which facilitates activation of muscle fibers to meet the demands of a given task. Selective recruitment of high threshold motor units was initially observed during heightened amplitudes of action potential and threshold torques during active lengthening, a muscle action characterized by muscle attachments being drawn farther apart (29,31).

Muscular determinants of RFD, such as muscle fiber type composition as denoted by its myosin heavy chain isoform content, muscle size, architecture, arrangement of muscle fibers, and musculotendinous stiffness. Fiber type composition is the most notable determinant of RFD as Type II muscle fibers are distinguished by greater $Ca2+$ release per action potential, faster time constants of $Ca2+$ currents, and hastened isoform activity lending itself to rapid cross-bridge cycling rates and thus faster muscular contractions (25).

Muscle size, specifically greater PCSA, is closely correlated with MVC and RFD. The increased RFD is attributed to increased pennation angles that account for greater PCSA, as more sarcomeres are arranged in parallel. This is noted among resistance trained subjects as increased pennation within pennate muscles enable increased muscular force (10). Musculotendinous stiffness is also a contributor to RFD. During movements, especially under appreciable external loads, musculotendinous tissue serves as a conduit of force. The speed at which force is transmitted through a material is dependent upon the stiffness of the material (25). The activity of contractile components during concentric muscle actions eventuating in contraction, and eccentric muscle actions eventuating in active lengthening, emit tensile forces that influence stiffness. For instance, when a muscle is subjected to force that exceeds the momentary force generated by the muscle itself, an eccentric muscle action or active lengthening of the muscle transpires that increases stiffness (14). The kinetic energy associated with the eccentric muscle action can be recoiled to contribute to the subsequent concentric muscle action, depending upon the velocity of the eccentric muscle action (14).

REVIEW OF THE LITERATURE

Resistance training modalities, including both heavy-resistance strength training, performed with near maximal external loads, and explosive-type strength training have been shown to improve RFD (10,25). For athletes, it is critically important that force be generated as quickly as possible to execute tasks specific to their sport or event. Noting this, Louie Simmons, renowned powerlifting coach and founder of Westside Barbell, began to incorporate the dynamic effort (DE) method, characterized by performing barbell exercises, including the bench press, with loads representative of 30 – 55% of an athlete's 1RM (36). The DE method has since been popularized by the strength and conditioning industry and embraced by athletes to improve explosiveness, or "starting strength," from the initiation of the concentric phase, such as "popping off" or "exploding off" the chest.

Loads representative of 30 – 70% of 1RM evoked greater mean and peak power in comparison to heavier loads performed with ≥ 70% of 1RM plausibly due to greater recruitment of high threshold motor units and increased rate coding and synchronization of motor units (42). In contrast, loads performed with ≥ 70% of 1RM elicit longer contraction times stemming from adaptations related to neural drive and peripheral muscle properties. DE method training encompassing submaximal loading elicited improvements in squat and bench press performance over six weeks, likely attributable to improved RFD via streamlined motor unit recruitment, synchronization, and increased discharge frequency (30).

An approach of movement intention, or "mind over matter," commonly referred to as Compensatory Acceleration Training (CAT), has captured the attention of strength and conditioning professionals as it has been shown to tender improvements in RFD and strength. CAT is predicated on utilizing moderate to heavy loads performed with intent, or premeditated effort, which has been shown to garner enhanced motor unit recruitment and streamlined rate coding performance (4). CAT protocols have been shown to elicit enhancements in RFD and muscle activation comparable to conventional isotonic resistance training and contribute to improvements in explosive and maximal strength (16,47).

A study involving CAT-style bench presses performed with maximal speed elicited greater improvements in strength performance and RFD in comparison to self-selected speed over a three-week period (34). Twenty resistance trained subjects were randomly split into two groups and performed bench presses at 85% of 1RM twice weekly over the course of three weeks. The first group performed bench presses at 80 – 100% maximal speed, terminating once velocity decreased by 20%. The second group performed bench presses at a self-selected speed until reaching failure. Following the conclusion of the protocol, significant increases in both muscular strength ($p = .002$) and velocity ($p = .006$) were achieved by the group performing bench presses at maximal speed.

Accommodating or variable resistance training, another modality popularized by Louie Simmons, which has been widely adopted by athletes, involves affixing chains, discs, elastic bands, or other accessories to accommodate an individual strength curve on a specific movement. Strength curves denote alterations in muscular activation patterns, lengths, joint angles, and corresponding lengths of joint and resistance arms. Accommodating or variable resistance is aimed at mitigating changes in barbell velocity, helping athletes surmount "sticking points," which in turn, can harmonize movement and result in a successful lift. Sticking points are characterized by deceleration or a transient pause of upward barbell movement because of poor mechanical force position or leverage (28) through insufficient strength or achievement of momentary muscle failure of specific muscles, such as the anterior deltoid and triceps brachii, which have been implicated in failed bench press attempts (28,49). Variable resistance involving bands was shown to elicit acute improvements in RFD (39). The applicability of variable resistance training to improve RFD was established by a recent meta-analysis consisting of seven studies comprised of 253 subjects (41). Long-term variable resistance training involving both bands and chains was shown to improve RFD and resultant maximal strength among athletes, non-athletes, and untrained subjects (41). Variable resistance, in conjunction with CAT, was shown to improve bench press performance among Division I athletes over a period of five weeks. Two groups who performed variable resistance with either bands or chains with CAT improved their maximal bench press by 11.6% (11.74 kg) and 11.8% (11.75 kg), respectively; whereas, the group who only incorporated variable resistance in the form of bands increased their bench press by 8% (16).

Lighter loads on the bench press performed explosively have been shown to contribute to increased throwing velocity among team handball players (27). Strength training consisting of repetitions performed at higher velocities are recommended for both combat sport athletes, though optimal loading parameters to enhance RFD among athletes with higher training ages and greater strength is 80% 1RM, whereas for lesser experienced athletes was found to be 65% 1RM (20). RFD was a key determinant of punching power, which could be honed by incorporating pressing exercises performed at higher velocities (37). These findings were corroborated by a more recent study that revealed low to moderate loads (40 – 60% 1RM) performed to exhaustion on the bench press exercise with maximum intended velocity or CAT yielded activation patterns of pectoralis major and triceps brachii muscles similar to heavier loads (80% 1RM) (48).

PRACTICAL APPLICATION

Incorporating training modalities such as the DE method and CAT in bench press training and incorporating accessories to accommodate the strength curve on the bench press exercise can improve RFD among athletes. Engendering movement intention or maximum intended velocity among athletes has immense applicability as it can evoke improvements in RFD, habituate maximal volitional efforts correlative with game or competition speed, and requires no additional equipment. Lighter loads can be used in conjunction with heavier loads in bench press training to develop RFD and maximal or limit strength simultaneously among novices or those with lower training ages. Whereas a blend of both heavier and lighter loads can be deployed within the same week via undulating periodization, exhibited by deliberate fluctuations in intensity and volume (12); or, within the same training session through contrast training typified by combining heavy resistance exercise with a high velocity movement of the same biomechanical pattern or a counterpart of the original resistance exercise with a reduction in load (9). Among athletes with higher training ages, training for RFD should be prioritized because RFD has greater correspondence to sports performance than maximal or limit strength. The DE method and CAT can continually be progressed in bench press training in external load (proportional to changes, or improvements in 1RM performance), volume (sets and repetitions), tonnage or total load lifted during a session across sets and repetitions, or by increasing density or the amount of work via sets and repetitions performed in fixed or predetermined allotment of time.

CONCLUSION

RFD is critical to bench press performance and more broadly sport performance. Similar to a range of fitness qualities, RFD is highly trainable and improvements within RFD can deliver improvements in strength following weeks of targeted training programs incorporating a blend of the DE method, CAT, and variable resistance modalities concurrently or independently. Improving RFD on the bench press can augment maximal or limit strength, which may be of particular interest or relevance to athletes, fitness professionals, strength and conditioning coaches, and members of the rehabilitation and sports medicine communities.

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