Journal of Strength and Conditioning Research, 1999, 13(1), 76–81

Comparison of Strength Differences and Joint Action Durations Between Full and Partial Range-of-Motion Bench Press Exercise

SWAPAN MOOKERJEE AND NICHOLAS RATAMESS

Exercise Physiology Laboratory, Bloomsburg University, Bloomsburg, Pennsylvania 17815.

ABSTRACT

The purpose of this investigation was to study strength differences following an acute exposure to full and partial range-of-motion (ROM) bench press exercise. In addition, we studied elbow joint action durations (via electrogoniometry) during full ROM and partial ROM one repetition maximum (1RM) and five repetition maximum (5RM) bench press exercise. Five strength-trained, male volunteers, age (mean ± *SD*) 25.6 ± 3.36 years, were tested on two separate occasions separated by 4 days. Results indicate that partial ROM bench press performance increased significantly for both the 1RM and 5RM conditions (4.8 and 4.1%, respectively, $p < 0.05$). Joint action durations during the flexion phase were significantly shorter than the extension phase for the full ROM 1RM only. For the 5RM, flexion durations increased significantly during both full and partial ROM ($p < 0.01$) but extensions showed no consistent pattern. This investigation, while demonstrating that strength differences can occur with an acute exposure to partial ROM resistance exercise, also provides insight into joint action durations in the execution of full ROM and partial ROM resistance exercise.

Key Words: joint action duration, strength training, electrogoniometry

Reference Data: Mookerjee, S., and N. Ratamess. Comparison of strength differences and joint action durations between full and partial range-of-motion bench press exercise. *J. Strength and Cond. Res.* 13(1):76–81. 1999.

Introduction

Muscular strength has been shown to vary throughout the range of motion (ROM) of a given joint (2, 4, 17, 24, 25, 26). Possible mechanisms for this phenomenon may be due to the muscle length–tension relationship (17, 24), moment arm length (17), and muscle activation and mass (25). Variations in strength can be depicted as strength curves (17), which permit the identification of areas of highest force output. Most of the literature focuses on isometric strength for single-joint movements, and limited data are available for dynamic, multijoint resistance exercises.

Dynamic partial range of motion (partial ROM) training is an advanced strength-training technique frequently utilized by athletes in many sports. Zatsiorsky (33) has described the accentuation principle, where the intent is to train in the range of motion where there is demand for maximal force production. One form of this type of training is designed to overload the musculoskeletal system with supramaximal loads (greater than 100% of one repetition maximum [1RM]) in the area of the ROM where maximal force is produced. It is believed that adaptations occur in response to the extreme overload via a decline in neural inhibition (28).

Studies on the bench press show an area of the ROM where maximal force production occurs (5, 18). For a dynamic lift, this ROM is beyond the ''sticking point'' near full elbow extension (5, 18). Wilson et al. (30) found that this area for an isometric bench press was at an elbow angle of 120°.

Most studies on dynamic partial ROM training were performed on clinical population samples in which subjects had limited ROM (9, 10). These studies showed that partial ROM training increased isometric strength at the specifically trained ROM and in full ROM (9, 10). Similarly, other studies using isometric training have demonstrated angular specificity of strength improvements and a spillover of strength of ±20° from the trained joint angle (14, 15, 24).

Sullivan and colleagues (23) studied moderately experienced, weight-trained subjects during the barbell curl exercise. They found partial ROM exercise produced greater torque compared to full ROM exercise. However, data on dynamic, partial ROM training-induced differences in muscular strength in advanced subjects is limited and needs to be addressed. Therefore, the purpose of this study was to (a) investigate strength differences following an acute exposure to full and partial ROM bench press exercise using 1RM and 5RM (five repetition maximum) and (b) describe elbow joint action durations during full and partial ROM bench press exercise at 1RM and 5RM.

Methods

Subjects

Five strength-trained males aged (mean ± *SD*) 25.6 ± 3.36 years participated in this study. The subjects' mean height, weight, and training experience were 178.1 ± 13.5 cm, 96.5 ± 27.2 kg, and 10.0 ± 4.18 years, respectively. Subjects had no prior experience in partial ROM training. Two subjects trained as bodybuilders, one subject trained as a power lifter, and two subjects trained as power bodybuilders.

Testing Protocol

Testing was conducted over a 2-day period separated by 4 days during which subjects continued to train but were instructed not to perform any bench press-related exercise. Prior to participation in the study, all subjects signed an informed consent form. A detailed description of the various tests is provided below. The full ROM 1RM was determined first in order to determine poundages that would be used in the 5RM lifts. During the second session, testing order was randomized.

Determination of Partial ROM. Subjects lay supine on a weight-lifting bench and grasped an unloaded bar with the elbows fully extended. A plastic goniometer was aligned with the lateral epicondyle to determine elbow joint angles. The bar was lowered until an elbow angle of 90° was attained. This area of the ROM was designated as the partial ROM. When an elbow angle of 90° was reached, bar position was held, and this point was marked on the upright of the bench with tape. The bar was then fully extended into the lockout position, which was also marked. Each subject was permitted to use his normal grip width to ensure maximal performance of the bench press.

Maximal Strength Assessments (Full ROM). The full ROM 1RM for the bench press was determined first. After a general warm-up, subjects proceeded to perform sets with progressively heavier weights using normal progression poundages for one to three repetitions with 3–5 minutes rest between sets. All subjects achieved their 1RM within five sets. The 5RM test was determined following the 1RM test using 80–85% of 1RM weight. Subjects were encouraged to perform repetitions to the point of fatigue.

Subjects were given 3–5 minute rest periods between lifts and 10 minutes between Full ROM and partial ROM lifts to allow for adequate recovery (26). Criteria for the correct execution of the bench press exercise were adhered to. Lifts not meeting all criteria were discarded. All lifts were performed as explosively as possible without a pause between the eccentric and concentric phases.

Maximal Strength Assessments (Partial ROM). Strength assessments for the partial ROM bench press were performed following the full ROM tests. Subjects were allowed to practice partial ROM lifts with an unloaded bar in order to enhance kinesthetic awareness of bar and joint positioning. During the first testing session, determination of the partial ROM 1RM was performed first, followed by the 5RM assessment. The format was similar to the full ROM assessments. Range of Motion was predetermined as described earlier. A spotter located horizontal and anterior to the lifter gave a verbal command to initiate the extension portion of the lift as soon as the bar was aligned with the lower tape mark on the upright.

Electrogoniometry

Two Norangle-Penny Giles electrogoniometers (Noraxon USA Inc., Scottsdale, AZ) were centered over the lateral epicondyle of the elbow and attached with tape. The data were sampled at a rate of 1,000 Hz. The electrogoniometers were calibrated against a plastic manual goniometer (Lafayette Instruments, Lafayette, IN). Reliability of these instruments was established using the method error of repeated measurements (22). The coefficient of variation for the left and right goniometers was 2.40% and 2.16%, respectively ($r = 0.99$ in both cases). Multiple marker analysis (Myosoft, Noraxon USA Inc.) was used to determine the durations for each phase (i.e., elbow flexion and extension).

Results

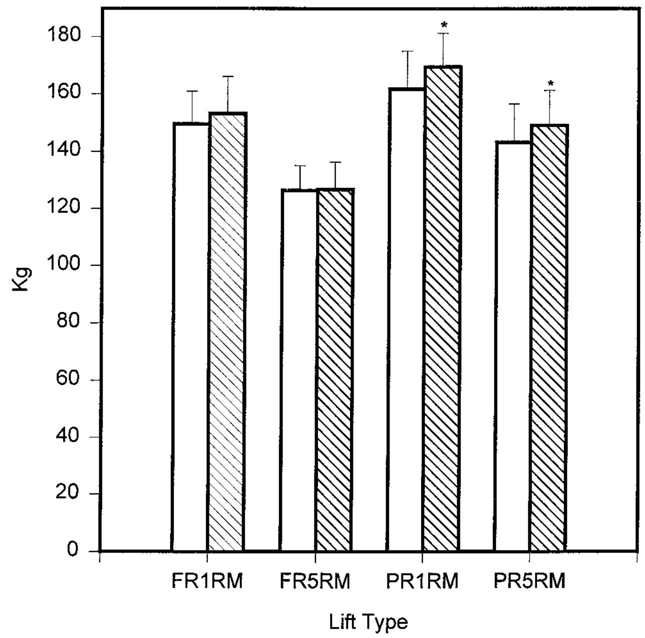
Strength Differences

Paired *t*-test analysis revealed no significant differences in the full ROM bench press for both 1RM and 5RM. However, there were statistically significant differences for the partial ROM 1RM and 5RM conditions ($p < 0.01$). The magnitude of the difference (i.e., $\delta =$ mean difference/mean pre $\times$ 100) was 4.78 and 4.13%, respectively. These results are depicted in Figure 1.

Joint Action Durations

The action durations (determined via electrogoniometry) were averaged for both elbow joints. Results of the 1RM action durations are presented in Table 1. There was a statistically significant difference between the full ROM flexion and extension phases ($p < 0.01$). Partial ROM and full ROM extension durations and partial ROM and full ROM flexion durations were not significantly different.

Results for 5RM muscle action durations are shown in Tables 2 and 3. Full ROM and partial ROM flexion action durations showed no consistent pattern between repetitions and appeared to be dependent on subject cadence preference. Full ROM and partial ROM extension durations showed a progressive increase from the first rep to the last rep. Compared to the first repetition, each of the succeeding full ROM reps were 8.3, 32.5, 106.4, and 169.1% longer, respectively ($p < 0.05$).



* Significant difference (p < 0.01) in PR lifts between testing sessions

Figure 1. Strength differences following full and partial ROM bench press exercise (mean ± *SD*).

Table 1. Elbow joint durations for 1RM bench press (ms) (mean ± *SD*).

Lift	Flexion	Extension
FR 1RM	1,724.06 ± 551.59	4,376.84* ± 981.34
PR 1RM	1,578.22 ± 383.26	2,490.44 ± 1,564.1

* Significant ($p < 0.01$).

Table 2. Elbow joint action durations for FR 5RM bench press (ms) (mean ± *SD*).

Rep number	Flexion	Extension
1	1,342.04 ± 662.96	1,223.96 ± 177.55
2	891.12 ± 303.05	1,325.96 ± 222.95
3	956.9 ± 452.11	1,621.60 ± 466.83
4	941.24 ± 460.21	2,526.40 ± 1,601.9
5	1,238.8 ± 807.34	3,293.08 ± 1,315.71

Table 3. Elbow joint action durations for PR 5RM bench press (ms) (mean ± *SD*).

Rep number	Flexion	Extension
1	1,191.30 ± 134.67	691.46 ± 133.21
2	1,103.30 ± 291.08	754.20 ± 147.20
3	1,073.10 ± 331.73	1,054.88 ± 177.66
4	1,249.80 ± 480.24	1,142.16 ± 156.42
5	1,338.52 ± 526.96	2,564.70 ± 1,825.07

Partial ROM extension action durations increased with each succeeding repetition by 9.1, 52.6, 65.2, and 270.9%, respectively ($p < 0.01$).

Compared to full ROM flexion repetitions, partial ROM flexion repetitions were longer in duration, except for the first rep, by −12.7, 23.8, 12.1, 32.8, and 8.1%, respectively, and 12.8% overall. In comparison with full ROM extension, partial ROM extension durations were shorter by 77.0, 75.8, 53.7, 121.2, and 28.4%, respectively, and by 71.2% on average.

Discussion

The initial finding in this study was the occurrence of a statistically significant difference in partial ROM bench press performance in advanced subjects who performed both full ROM and partial ROM bench press exercises. Following two testing sessions with 4 days during which subjects continued to train (only avoiding use of the bench press and any supplemental exercise), subjects' partial ROM bench press increased by 4.8 and 4.1% for the 1RM and 5 RM, respectively (see Figure 1). Individuals who train exclusively in a full ROM may fail to optimally train in the area of the ROM where maximal force developement occurs. This is possibly due to the load requirement for the full ROM bench press being limited by the "sticking point" (5).

Strength differences may have occurred due to motor leaning and coordination. Strength expression is a combination of factors such as volition, motorneuron activity, and the coordinated activation of the supporting musculature. Rutherford and Jones (21) have demonstrated that, in untrained subjects, the initial increases in strength were due to the coordinated activation of both the involved and stabilizing muscles. This type of learning effect may have played a role in the present study involving advanced subjects.

Loads used for the partial ROM bench press exceeded that of the full ROM bench press. During the second testing session, loads were 10.7 and 17.6% greater in the partial ROM for the 1RM and 5RM tests, respectively. These results corroborate previous work (5, 18, 31) on the bench press where this ROM was described as the area of maximal strength. The results also support the findings of Sullivan et al. (23), who reported greater torque production during performance of partial range of motion barbell curls.

The nonsignificant difference observed in maximal strength for the full ROM bench press could be explained by the fact that these were experienced subjects (mean training experience of 10.0 ± 4.18 years) who were accustomed to the bench press exercise.

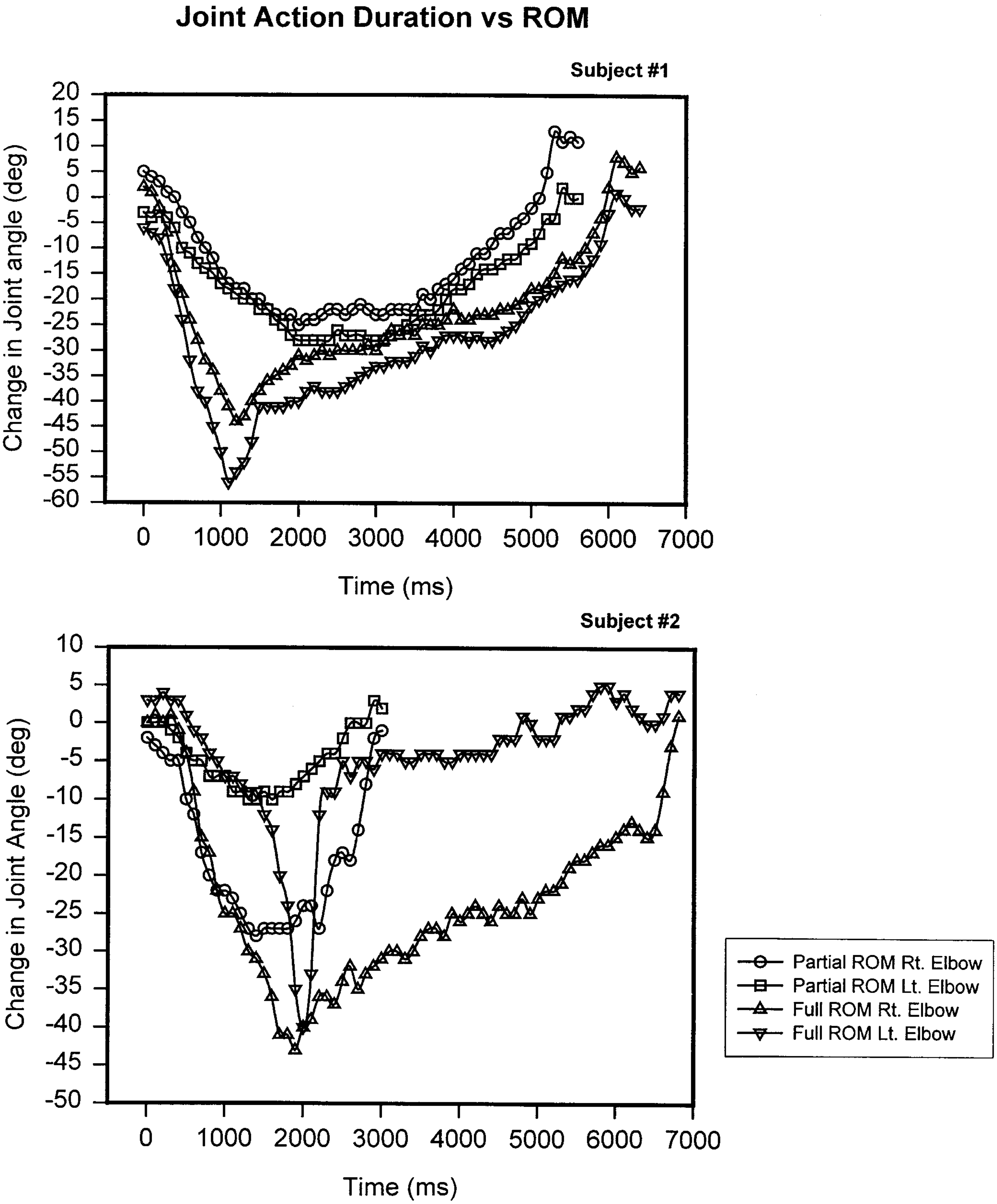


Figure 2. Example: Joint action duration vs. ROM plotted for 2 subjects.

Gains in muscular strength with an acute exposure to a given exercise are mainly dependent on neural and technique factors.

Flexion action durations for full ROM 1RM were significantly shorter than the extension durations ($p < 0.05$). This is explained by the fact that force development is greater eccentrically than concentrically (6, 7, 16). Thus, extension is the most difficult phase. The flexion phase is also affected by subject cadence, which is normally more rhythmic, rapid, and lacks a sticking point. For the partial ROM, the extension phase was longer (57.8%) but not significantly different. This may have been due to the greater load utilized. Subjects who were unfamiliar with the heavy loads associated with PR training may have been more tentative when lowering the weight.

In comparing full ROM and partial ROM 1RM, the flexion durations were not significantly different. With a limited ROM, it was expected that the flexion phase would be shorter in duration. Again, subject unfamiliarity and tentativeness to partial ROM exercise may have influenced these results.

The extension phase was 75.7% shorter for partial ROM, but this was not statistically significant. This was due to the smaller bar displacement for partial ROM and the lack of a true sticking point. Elliott et al. (5) found that the sticking region made up 28.8% of the total extension full ROM duration during a 1RM. Thus, bypassing the sticking region could significantly decrease extension action durations for partial ROM.

Flexion action durations for full ROM and partial ROM showed no consistent pattern from repetitions one through five. This may have been due to subjects' own cadence preferences. As a set progresses and fatigue occurs, some subjects will accentuate the eccentric phase of the exercise to gain more control while others increase flexion velocity near the bottom ROM of the lift to utilize the stretch shortening cycle (30) when no pause is utilized. Extension action durations increased with each succeeding repetition (see Tables 3 and 4) in which repetition five was 169.1% ($p < 0.05$) greater than repetition one for full ROM and 270.9% greater for partial ROM ($p < 0.05$). These results could be explained by muscle fatigue, in which performance of the repetitions became progressively more difficult.

Partial ROM 5RM flexion durations were 12.8% greater overall ($p > 0.05$) and occurred despite a lower ROM that the joint traversed. This may have been due to greater loads used and subject cadence preference. Partial ROM 5RM extension durations were 71.2% less than full ROM. These results were similar to the 1RM data.

Individual joint angle changes vs. time durations are plotted for two subjects in Figure 2. The top panel depicts curves for subject 1, who was free from any known orthopedic problems in the upper extremities. Subject 2, however, had a history of chronic problems in the right anterior shoulder region. In contrast to the upper panel, where the curves depicting the change in joint angles are evenly matched in both full ROM and partial ROM lifts, the bottom panel clearly reveals a pattern of asynchrony. This may have been a learned lifting style, where the subject was compensating for the affected shoulder by altering the ROM and joint action durations. Thus, these plots can provide a means for utilizing electrogoniometry for the purposes of analysis and feedback on lifting technique.

All subjects reported delayed onset muscle soreness (DOMS) in the anterior deltoid/pectoralis minor area for up to 2 days posttesting. It may have occurred because subjects performed high-intensity full ROM lifts, were unaccustomed to the greater loads in partial ROM, and accentuated the eccentric phase. Consequently, greater myofibrillar damage may have occurred.

The individuals involved in this study were at a plateau in the full ROM bench press but still exhibited significant differences with an acute exposure to the partial ROM and full ROM techniques. The partial ROM technique facilitates training with higher loads than is possible with full ROM movements. The effects of this supramaximal loading on specific physiological mechanisms related to strength performance, particularly in full ROM resistance exercise, remain to be elucidated. Future investigations using a control group and a partial ROM training group are needed to establish its efficacy as a possible complementary training technique.

Practical Application

Advanced level strength-trained athletes may eventually reach a point in training where little or no progress occurs. One way to overcome this plateau may be to include partial ROM training (with supramaximal loading) into the periodized training plan. Our results show that a significant difference in partial ROM bench press lifts can occur with a single exposure to this technique coupled with full ROM lifts. In addition, this investigation, while providing descriptive data on elbow joint action patterns in advanced lifters, also demonstrates how electrogoniometry can be used as a tool to provide feedback on lifting patterns and technique.

References

1. Callaway, C.W., W.C. Chumlea, C. Bouchard, J.H. Himes, T.G. Lohman, A.D. Martin, C.D. Mitchell, W.H. Mueller, A.F. Roche, and V.D. Seefeldt. Circumferences. In: *Anthropometric Standardization Reference Manual.* T.G. Lohman, A.F. Roche, and R.M. Martorell, eds. Champaign, IL: Human Kinetics, 1988. pp. 39–54.
2. Campney, H.K. and R.W. Wehr. Significance of strength variation through a range of joint motion. *Phys. Ther.* 45:773–779. 1965.

3. Carpenter, D.M., J.E. Graves, M.L. Pollock, S.H. Leggett, D. Foster, B. Holmes, and M.N. Fulton. Effect of 12 and 20 weeks of resistance training on lumbar extension torque production. *Phys. Ther.* 71:580–588. 1991.
4. Clarke, H.H., E.C. Elkins, G.M. Martin, and K.G. Wakim. Relationship between body position and the application of muscle power to movements of the joints. *Arch. Phys. Med. Rehab.* 31: 81–89. 1950.
5. Elliott, B.C., G.J. Wilson, and G.K. Kerr. A biomechanical analysis of the sticking region in the bench press. *Med. Sci. Sports Exerc.* 21:450–462. 1989.
6. Eloranta, V., and P.V. Komi. Function of the quadriceps femoris muscle under the full range of forces and differing contraction velocities of concentric work. *EMG Clin. Neurophysiol.* 20:159–174. 1980.
7. Eloranta, V., and P.V. Komi. Function of the quadriceps femoris muscle under the full range of forces and differing contraction velocities of concentric work. *EMG Clin. Neurophysiol.* 21:419–431. 1981.
8. Fleck, S.J., and W.J. Kraemer. *Designing Resistance Training Programs.* Champaign, IL: Human Kinetics, 1987.
9. Graves, J.E., M.L. Pollock, A.E. Jones, A.B. Colvin, and S.H. Leggett. Specificity of limited range of motion variable resistance training. *Med. Sci. Sports Exerc.* 21:84–89. 1989.
10. Graves, J.E., M.L. Pollock, S.H. Leggett, D.M. Carpenter, C.K. Fix, and M.N. Fulton. Limited range-of-motion lumbar extension strength training. *Med. Sci. Sports Exerc.* 24:128–133. 1992.
11. Hortobagyi, T., and F.I. Katch. Role of concentric force in limiting improvement in muscular strength. *J. Appl. Physiol.* 68:650–658. 1990.
12. Jackson, A., T. Jackson, J. Hnatek, and J. West. Strength development: Using functional isometrics in an isotonic strength training program. *Res. Q. Exerc. Sport* 56:234–237. 1985.
13. Kitai, T.A., and D.G. Sale. Specificity of joint angle in isometric training. *Eur. J. Appl. Physiol.* 58:744–748. 1989.
14. Knapik, J.J., R.H. Mawdsley, and N.V. Ramos. Angular specificity and test mode specificity of isometric and isokinetic strength training. *J. Orthop. Sports Phys. Ther.* 5:58–65. 1983.
15. Knapik, J.J., J.E. Wright, R.H. Mawdsley, and J. Braun. Isometric, isotonic, and isokinetic torque variations in four muscle groups through a range of joint motion. *Phys. Ther.* 63:938–947. 1983.
16. Komi, P.V. Training of muscle strength and power: Interaction of neuromotoric, hypertrophic, and mechanical factors. *Int. J. Sports Med.* 7:10–15. 1986.
17. Kulig, K., J.G. Andrews, and J.G. Hay. Human strength curves. *Exerc. Sports Sci. Rev.* 12:417–466. 1984.
18. Lander, J.E., B.T. Bates, J.A. Sawhill, and J. Hamill. A comparison between free-weight and isokinetic bench pressing. *Med. Sci. Sports Exerc.* 17:344–353. 1985.
19. Madsen, N., and T. McLaughlin. Kinematic factors influencing performance and injury risk in the bench press exercise. *Med. Sci. Sports Exerc.* 16:376–381. 1984.
20. Pollock, M.L., S.H. Leggett, J.E. Graves, A. Jones, M. Fulton, and J. Cirulli. Effect of resistance training on lumbar extension strength. *Am. J. Sports Med.* 17:624–629. 1989.
21. Rutherford, G.M., and D.A. Jones. The role of learning and coordination in strength training. *Eur. J. Appl. Physiol.* 55:100–105. 1986.
22. Sale, D.G. Testing strength and power. In: *Physiological Testing of the High-Performance Athlete.* J.D. MacDougall, H.A. Wenger, and H.J. Green, eds. Champaign, IL: Human Kinetics, 1991. pp. 76–77.
23. Sullivan, J.J., R.G. Knowlton, P. DeVita, and D.D. Brown. Cardiovascular response to restricted range of motion resistance exercise. *J. Strength Cond. Res.* 10:3–7. 1996.
24. Thepaut-Mathieu, C., J. VanHoecke, and B. Maton. Myoelectrical and mechanical changes linked to length specificity during isometric training. *J. Appl. Physiol.* 64:1500–1505. 1988.
25. Tsunoda, N., F. O'Hagan, D.G. Sale, and J.D. MacDougall. Elbow flexion strength curves in untrained men and women and male bodybuilders. *Eur. J. Appl. Physiol.* 66:235–239. 1993.
26. Weir, J.P., L.L. Wagner, and T.J. Housh. The effect of rest interval length on repeated maximal bench presses. *J. Strength Cond. Res.* 8:58–60. 1994.
27. Williams, M., and L. Stutzman. Strength variation through the range of joint motion. *Phys. Ther. Rev.* 39:145–152. 1959.
28. Wilson, G. Strength and power in sport. In: *Applied Anatomy and Biomechanics in Sport.* J. Bloomfield, T. Ackland, and B. Elliott, eds. Boston: Blackwell Scientific Publications, 1994. pp. 110–208.
29. Wilson, G.J., B.C. Elliott, and G.A. Woods. The effect on performance of imposing a delay during a stretch–shorten cycle movement. *Med. Sci. Sports Exerc.* 23:364–370. 1991.
30. Wilson, G.J., B.C. Elliott, and G.K. Kerr. Bar path and force profile characteristics for maximal and submaximal loads in the bench press. *Int. J. Sport Biomech.* 5:390–402. 1989.
31. Wilson, G.J., A.J. Murphy, and J.F. Pryor. Musculotendinous stiffness: Its relationship to eccentric, isometric, and concentric performance. *J. Appl. Physiol.* 76:2714–2719. 1994.
32. Wilson, G.J., G.A. Wood, and B.C. Elliott. Optimal stiffness of series elastic component in a stretch–shorten cycle activity. *J. Appl. Physiol.* 70:825–833. 191.
33. Zatsiorsky, V. *Science and Practice of Strength Training.* Champaign, IL: Human Kinetics, 1995.

Acknowledgments

The authors are indebted to Michael Rowling (Noraxon USA, Inc) for providing technical support and expertise during this study. This study was partially supported by funds from the Bloomsburg University Alumni Association, and the Bloomsburg University Office of Graduate Studies and Research.

Note: Nicholas Ratamess is now with the Human Performance Laboratory, Exercise Science Program, Ball State University, Muncie, IN 47306.