International Journal of Physical Education and Sports Sciences

Vol. IV, No.I, October-2012, ISSN 2231-3745

REVIEW ARTICLE

AN ANALYTICAL STUDY OF PHYSICAL EDUCATION IN SPECIAL REFERENCE TO STRENGTH TRAINING

www.ignited.in

International Journal of Physical Education and Sports Sciences
Vol. IV, Issue I, October-2012, ISSN 2231-3745

An Analytical Study of Physical Education in Special Reference to Strength Training

Rajnessh Nanda

Research Scholar, Sri Venkateshwara University (U.P.)

---------------------------♦-----------------------------

INTRODUCTION

The results from this study showed that following an eccentric elbow flexor training program, there was an increase in strength and muscle thickness of the elbow flexors in young boys. The difference in the changes in the training arm between the maturational groups was non-significant ($p > 0.05$), for both strength and muscle thickness. These results indicate that training had the same affect on muscle strength and thickness in both maturational age categories.

In the whole group, eccentric strength training had a significant effect ($p < 0.05$) on muscle thickness and maximal strength of the training arm when compared to the non-training arm. The training arm increased significantly more ($p < 0.05$) than the non-training arm for eccentric isokinetic maximal strength, and both concentric and eccentric isotonic maximal strength. These results provide evidence to support the study hypothesis that eccentric strength training will increase muscle strength and muscle thickness in young boys.

Most recent studies have shown increased strength following a strength training program in preadolescent/adolescent boys (Malina, 2006). However, the upper body strength gains reported are normally of lesser extent than the gains in the current study. This is especially true when looking at the eccentric isotonic increases (Table 3.6), although no other studies have tested for eccentric strength gains. For changes in muscle thickness, or hypertrophy, it is generally reported that this type of morphological change does not occur in preadolescence (Behm et al., 2008). Our results show that strength training can increase muscle thickness, even in preadolescence. It is hypothesized that the reason for the morphological changes in this study is due to the high intensity strength training that was employed using eccentric contractions, as well as a heavy volume of repetitions and sets.

STRENGTH AND MUSCLE THICKNESS IN THE TRAINED ARM

Strength training affects young boys differently depending on if they are pre or early pubescent versus late pubescent (Sewall & Micheli, 1986). Some research has shown strength increases are minimal for pre-pubertal boys when compared to their older peers (Blimkie, 1992). However, strength gains made by pre-pubertal boys following a strength training program are similar, or sometimes even greater when expressed relatively, than the gains made by late pubertal or early adults following a program of similar intensity (Pfeiffer & Francis, 1986). The first analysis in this thesis was performed to determine if there were any significant differences between the changes in the training arm between the two different maturational groups. Hence, it was performed to determine if maturation status would differentially affect any changes the strength training program may cause. When comparing the change in elbow flexor strength and muscle thickness in the training arm between maturational groups there was no significant difference ($p > 0.05$). This shows that the strength training had the same effect on both strength and muscle thickness for the two maturational categories. These strength results are similar to what has been previously found. Studies by, Pfeiffer and Francis (1986), and Sailors and Berg (1987), reported similar relative strength increases in pre-pubertal boys when compared to late pubertal and young adult men.

One of the limiting factors of muscle hypertrophy and strength in pre-pubertal boys is the low serum levels of testosterone (Payne et al. 1997). Testosterone is often said to be the most important hormone for natural growth and development (Blimkie & Sale, 1998). Therefore the large increase in testosterone in boys (Figure 1-4), which occurs approximately one year prior to PHV (Malina & Bouchard, 2001), could play a major role in how the body adapts physiologically to the stresses that strength training imposes on the muscular system.

Although testosterone does have an obvious impact on muscle strength and hypertrophy, it is not solely responsible for it. One study showed that testosterone only accounted for 41% of the variability in strength in young boys (Ramos et al., 1998). Another study found that grip strength levels in both males and females were independent of hormones. Also, an interesting finding in the study by Tsolakis et al. (2001) showed that strength training in preadolescent males actually increases testosterone levels, as well as the free androgen index, and these increased levels remain two months after completion of the training program. Although the research in this area is limited, possible strength training effects in pre-pubertal boys cannot be ruled out solely on this reported low level of testosterone.

Although APHV was not calculated from longitudinal data, which is the most accurate, it was derived using a formula developed by Mirwald et al. (2002). This formula accurately predicts age of PHV within 0.5 years. Comparing descriptive statistics between the groups, as expected the more mature group (i.e. those deemed to be within one year of PHV or older) was significantly ($p < 0.05$) taller and heavier than their younger peers. This provides evidence that the two groups were in fact maturationally distinct. Assuming this is true, and having found no significant difference between the two groups for the change in muscle thickness or strength, it is fair to conclude that in this study, the maturational age categories did not have a significant differential effect on any possible adaptations of strength or hypertrophy. With this conclusion, the remainder of the analysis was performed using whole group data to determine any differences between the training and non-training arms, following the strength training program.

MUSCLE THICKNESS

Measuring change in muscle thickness is essentially measuring the amount of muscle hypertrophy that has occurred. An increase in muscle thickness, or muscle CSA, would be almost entirely attributed to an increase in myofibrillar size and number (Folland & Williams, 2007). Chronic exposure to strength activities increases muscle hypertrophy in adults (Favier et al., 2008). In pre and early pubertal boys this is not the case, as there have been only two previous studies which have provided some evidence of any apparent hypertrophy in children of this age (Behm et al., 2008). The results from these two studies (Mersch & Stoboy, 1989; Fukunaga et al., 1992) have been discredited in the majority of the research due to the numerous other studies which have shown no significant hypertrophy, and study flaws which have been previously stated.

The results from this study show a greater increase in muscle thickness in the training arm when compared to the non-training arm at all three sites. The percent change at the three sites; distal, medial, and proximal, were 5.2%, 7.8% and 8.9% respectively, with the latter two sites showing a significant pre post increase ($p<0.05$). These results are similar to those reported by Mersch and Stoboy (1989), which ranged between 4 and 9%. Hypertrophy studies on adults have shown a wide range of percent changes in muscle thickness. In a recent study that employed a similar training program, muscle group, and muscle thickness measure, a 13% change was reported for the “fast eccentric” group, and 7.8% for the “slow eccentric” group (Farthing & Chilibeck, 2003b). The changes reported in the non-training arm in the current study were not significant for any of the sites; distal -1.1%, medial 0.1%, and proximal 1.8%. Although there was actually a decrease in muscle thickness at the distal site, this decrease was non-significant ($p > 0.05$), and it is within the measurement error range which has been reported in previous muscle ultrasound studies. The muscle thickness results from the current study conflict with most research on this topic. It has been widely reported that pre-pubertal boys are unable to increase muscle mass through strength training until they reach a certain biological age (Payne et al., 1997; Faigenbaum & Kang, 2006; Behm et al., 2008).

These results could be due to a couple of different factors. One is the ability to control for maturation due to the within subject design. Most other studies use an exercise group and a control group, and although they often try to control for maturity by assessing it using various methods, it is impossible to account for all the individual differences. At this stage of development, it is especially hard to control for maturity and therefore the ability of the researcher to separate the effects of the training from the effects of natural growth and development. Another factor which may have led to the significant hypertrophy not normally shown is the strength training program which was employed in this study. Eccentric training has not been used in adolescent strength training studies, and in adults, several studies have shown that it is more beneficial then concentric or isometric strength training programs (Hortobáygi et al., 1996; Farthing & Chilibeck, 2003b). The intensity and volume of this study was greater than most other youth training studies, and these factors play a major role in the amplitude of hypertrophy in adults. So this may be true for adolescents as well. Another factor which could have played a role is the choice of muscle group. Upper body muscles are more responsive to strength training, in terms of muscle hypertrophy, than those of the lower body (Folland & Williams, 2007). Most other child strength training studies have examined hypertrophy of the lower body or whole body muscles (Behm et al., 2008), whereby the focus of this study was to examine only changes in the elbow flexors.

ISOKINETIC STRENGTH

The current study found eccentric isokinetic strength increased significantly ($p < 0.05$) in the training arm compared to the non-training arm. The relative reported change was 25.4% versus 2.4%. The concentric isokinetic strength in the training arm increased 11.4% versus 2.2% for the non-training arm. Although the concentric change displayed a trend to be greater in the training arm, the increase was not significant compared to the untrained arm ($p > 0.05$). There are no previous studies that tested eccentric strength in children, so there is no comparison for the values obtained in this study.

However, there have been a couple of studies that have performed concentric strength testing on an isokinetic hydraulic resistance machine. Weltman et al. (1986) showed pre-pubertal boys increased concentric strength an average of 27% following a 14 week training program. Rians et al. (1987) showed a range of 21% to 32% improvement in concentric strength, also following 14 weeks of strength training. The higher values of concentric strength reported in these two studies may be due to specificity of training. Both studies trained concentrically using the same hydraulic resistance machine that was used for testing. Also, their training programs were almost twice as long as the one employed in the current study. However when comparing eccentric strength to the values of these two studies, the numbers are very similar. This again provides evidence for specificity of training, as the change in eccentric strength was almost twice that of the concentric strength.

ISOTONIC STRENGTH

Free weight (isotonic) strength training and/or testing is more common in youth strength training studies than isokinetic training and/or testing. This study reported a significant increase ($p < 0.05$) in both concentric and eccentric elbow flexor strength, when compared to the non-training arm. Concentric strength increased 35.0% for the training arm and 14.8% for the non-training arm. Eccentric strength increases were 45.0% and 21.8%, with the training arm once again being greater. Numerous studies have examined changes in concentric isotonic strength following a strength training program (Ozmun et al., 1994; Pfieffer& Francis, 1986; Ramsay et al., 1990; Sewell & Micheli, 1986). The percent improvement ranges anywhere between 10% and 40%. Most of these studies employed a light to medium intensity, with a repetition range of 8 – 12 and duration of 8 – 20 weeks. The 35% increase reported in this study is in the higher range of these results. This could be due to the previously mentioned factors of high intensity and volume of work during each training session. Also, as with hypertrophy, eccentric training is more beneficial for strength improvement than concentric training (Farthing & Chilibeck, 2003b). There are two studies which reported higher than average strength increases. Faigenbaum, Wescott, and Micheli (1996) and Sailors & Berg (1987) reported strength increases of up to 54% and 52%

respectively. As with the current study, both of these studies were eight weeks in duration and used isotonic resistance. Also, both employed a low repetition range (5 – 8 reps) with maximal intensity, which is the type of program design that has been proven more beneficial for strength development than high repetition low intensity workouts (Kraemer & Ratamess, 2003). For isotonic strength, the non-training arm also showed significant improvement ($p < 0.05$) from pre to post, both concentrically and eccentrically. A possible explanation for this could be the phenomenon known as cross-education. This is a neural adaptation that can occur following unilateral strength training where the strength of the non-trained contralateral limb increases as well (Lee & Carroll, 2007). This effect was more pronounced in the isotonic testing versus the isokinetic testing. This shows evidence of movement specific cross-education, as the training was isotonic.

STUDY LIMITATIONS

A major limitation of this study was the small sample size. Prior to recruitment a power calculation was performed, and it was determined a sample size of 17 was needed to have 80% power. There were 17 subjects who completed the current study, which was in line with the suggested sample size from the power calculation. However, when the group was split into two separate maturational groups, the recommended sample size was not met. Therefore, the between group analysis performed was underpowered, and this may have had an impact on the lack of any significant findings.

Another limitation was the age range of the boys. There was a range in biological age of 12.1 years to 14.3 years, and the range for maturational age was -2.0 YPHV to 1.2 YPHV. Therefore the boys were at very distinct parts of their development, and with numerous physiological changes which occur during this critical period; this may have an effect on the changes that were reported. However, it should be noted that the comparison between the two different maturational groups showed no difference in relative strength or hypertrophy adaptations following strength training. Having only one group of pre-pubertal boys would strengthen the study, as this is the age where hypertrophy is thought not to occur. Another related limitation is the estimation of maturational age using a prediction formula. Having longitudinal data on each child's growth pattern would allow for a more accurate estimation of

PHV THIS HOWEVER, AS WITH MOST STUDIES, IS NOT USUALLY A FEASIBLE OPTION.

There are a couple limitations regarding the use of the ultrasound for muscle thickness measurements. Adipose tissue was not taken into consideration when performing the measurement, yet adipose tissue does account for a small amount of the thickness measured. It was thought that over an eight week timespan any change in adipose tissue in the upper arm would be negligible, however in some extreme cases this may not be true. Researcher bias is also a limitation, because for the muscle thickness measure, as well as the strength testing, the tester was not blinded to the training intervention.

Probably the greatest limitation of this study is the failure to test for important physiological variables which may account for strength or hypertrophy adaptations. The importance of hormonal changes in growth studies, as well as strength training studies has been repeatedly stressed. Therefore testing for hormones, specifically testosterone, growth hormone, and IGF-1, would greatly enhance a study of this design. As an added benefit for this testing, it could assist in assessing maturational age. Another physiological variable which plays a large role in strength development is neuromuscular adaptations. Therefore, using EMG measurements would also be very valuable.

RECOMMENDATIONS FOR FUTURE RESEARCH

Future research in this area should test for other physiological variables. As mentioned when discussing the limitations of the current study, hormonal changes and neurological adaptations are of great importance and should be tested for. Performing EMG measurements during maximal strength testing would allow the researcher to better explain the change in strength. Testing for different hormones in children may increase difficulty for subject recruitment, or ethical approval, but the information gained would prove invaluable. However, using salivary hormone measurements, which are less invasive than blood measurements, would be a feasible option. Incorporating a control group into a study design similar to this one would be advantageous as any learning effect from the familiarization and baseline testing on the post testing would be shown.

As this study focused only on elbow flexor muscles, future research could look at the effects of eccentric training on other muscle groups. Also, the effects of varying training programs, in terms of intensity, volume, and duration could be examined. The applicability of eccentric training on sport performance in young athletes is another area worth researching.

One area where more research is definitely needed, and not only in regards to eccentric training and muscle hypertrophy, is the effects of strength training in young girls, as this area is often overlooked.

Future research should also examine the effects of eccentric training, as well as strength training in general, on various health components. If hypertrophy in young children is possible, eccentric training may be a possible treatment for atrophic childhood diseases. Also, some studies have been performed on strength training as a possible treatment for childhood obesity, and the results from these studies are favourable (Benson, Torode, & Singh, 2008b). However, not many have looked at it as a strategy for prevention of obesity in young children. Information on the relationship between body composition and strength training in children is limited. Also, it would be interesting to determine if strength training can have similar effects on basal metabolic rate and excess post-exercise oxygen consumption (EPOC) in children as it does in adults (Bloomer, 2005). Research on the application of strength training in children for health benefits is extremely limited. However this is an area which could be important as the incidence of childhood obesity continues to increase (Benson, Torode, & Singh, 2008a).

SUMMARY

Strength training in children is an area dominated by negative myths, and as a result was viewed as dangerous and impractical mode of exercise which should be avoided (Faigenbaum & Kang, 2006). However, most of the recent research has shown strength training is a safe mode of exercise with numerous health benefits and is now recommended as a valuable part of any child's suggested activity (Behm et al. 2008). Physiological research in this area is limited (Strong et al., 2005), however, it is now generally accepted that strength training in pre-pubertal and pubertal children will increase strength, but it is unlikely to induce

morphological changes. The majority of research has been limited by two major flaws. One is a failure to control the effects of natural strength and development; and two, employing a training program with insufficient intensity required to produce significant adaptations (Faigenbaum, 2000). To overcome these limitations it is suggested that researchers should use

a within-subject design employing an exercise regime of sufficient intensity. Research in adults indicates eccentric training causes the greatest increases in strength and hypertrophy (Farthing & Chilibeck, 2003b); however this mode of exercise has not been utilized in any youth training studies. The current study used a one arm training study to investigate the effects of an eccentric training program on both muscle strength and hypertrophy in pre- pubertal and pubertal boys.

Seventeen boys in grades 6, 7, or 8 participated in an eight week eccentric training program. The training was performed three days per week, for a total of 24 sessions, and consisted of 2 – 5 sets of 6 – 10 repetitions of dumbbell biceps curls at a controlled tempo using progressive resistance. Pre and post elbow flexor muscle thickness was measured using B-mode ultrasound (Aloka SSD-500). Strength was measured pre and post using an isokinetic dynamometer (Biodex System 3, Biodex Medical Systems), as well as one repetition maximum using dumbbells. Strength measurements were performed on both arms, both concentrically and eccentrically. Muscle thickness increased significantly in the trained arm compared to the untrained arm. No significant difference was found for isokinetic concentric strength; however isokinetic eccentric strength increased significantly greater in the trained arm versus the untrained arm. Training arm one repetition maximum increased significantly greater than the untrained arm for both concentric and eccentric isotonic contractions. The changes that occurred due to the training program were not different between the two maturational age categories.

CONCLUSIONS

Results from this study indicate eccentric strength training can increase muscle strength and hypertrophy in pre-pubertal and pubertal boys. Further, these results appear to be maturational independent.

REFERENCES

Almond, L. (1996) The Place of Physical Education in Schools. 2nd edn. London: Kogan Page. Bain, L. (1976) 'Play and intrinsic values in physical education', Quest, 26: 75–80.

Barrow, R. (1981) The Philosophy of Schooling. London: Harvester.

Best, D. (1978) Philosophy and Human Movement. London: George Allen and Unwin.

Brackenridge, C. and Alderson, J. (1982) 'A classification of sports', British Association of Sports Science Conference.

Carlisle, R. (1969) 'The concept of physical education', Proceedings of the Philosophy of Education Society of Great Britain, 3: 1–11.

Carr, D. (1979) 'Aims of physical education', Physical Education Review, 2 (2): 91–100.

Carr, D. (1997) 'Physical education and value diversity: a response to Andrew Reid', European Physical Education Review, 3 (2): 195–205.

Cooper, D. (ed.) (1986) Education, Values and Mind. London: Routledge and Kegan Paul. Dearden, R.F. (1968) The Philosophy of Primary Education. London: Routledge and Kegan Paul.

Evans, J. and Davies, B. (1993) 'Equality, equity and physical education', in J. Evans (ed.), Equality, Education and Physical Education. London: Falmer Press. pp. 11–27.

Evans, J. and Penney, D. (2002) 'Introduction', in D. Penney (ed.) Physical Education. Contemporary Issues and Future Directions. London: Routledge. pp. 3–13.

Kirk, D. (2002) 'Junior sport as a moral practice, Journal of Teaching in Physical Education, 21: 402–8. Hirst, P.H. and Peters, R.S. (1970) The Logic of Education. London: Routledge and Kegan Paul.

Hogenova, M. (2002) 'Legality and legitimacy in sport', European Journal of Sport Science, 2 (1): 1–6. http://www.humankinetics.com/EJSS/viewarticle.cfm?aid=120 http://www.humankinetics.com/EJSS/viewarticle.cfm?aid=120

Kleinig, J. (1983) Philosophical Issues in Education. Sydney: Croom Helm.

Lehman, C. (1982) 'Can cheaters play the game?', Journal of Philosophy of Sport, 8: 41–6. McIntyre, A. (1985) After Virtue. A Study in Moral Theory. London: Duckworth.

McNamee, M.J. (1988) 'Health-related fitness and physical education', British Journal of Physical Education, 19 (2): 83–4.

McNamee, M.J. (1992) 'Physical education and the development of personhood', Physical Education Review, 15 (1): 13–28.

McNamee, M.J. (1994) 'Valuing leisure practices: towards a theoretical framework', Leisure Studies, 13 (1): 288–309.

McNamee, M.J. (1995) 'Sporting practices, institutions, and virtues: a critique and a restatement', Journal of Philosophy of Sport, XXII: 61–82.

McNamee, M.J. (1998a) 'Contractualism and methodological individualism and communitarianism: situating understandings of moral trust', Sport, Education and Society, 3 (3): 161–79.

McNamee, M.J. (1998b) 'Education, philosophy and physical education: analysis, epistemology and axiology', European Physical Education Review, 4 (1): 75–91.

Meakin, D.C. (1982) 'Moral values and physical education', Physical Education Review, 5 (1): 62–82.

Meakin, D.C. (1990) 'How physical education can contribute to personal and social education', Physical Education Review, 13 (2): 108–119.

Morgan, W.P. (1987) 'Formalism and the logical incompatibility thesis', Journal of Philosophy of Sport, 14: 1–20. Nozick, R. (1974) Anarchy, State and Utopia. Oxford: Blackwell.

Parry, S.J. (1988) 'Physical education, justification and the national curriculum', 11 (2): 106–18.

Parry, S.J. (1998) 'Physical education as Olympic education', European Physical Education Review, 4 (2): 153–167. Peters, R.S. (1966) Ethics and Education. London: Allen and Unwin.

Plato (1974) The Republic, 2nd edn. (trans.) D. Lee. London; Penguin, pp. 102–4. Rawls, (1972) A Theory of Justice. Oxford: Oxford University Press.

Reid, A. (1996a) 'The concept of physical education in current curriculum and assessment policy in Scotland', European Physical Education Review, 2 (1): 7–18.

Reid, A. (1996b) 'Knowledge, practice and theory in physical education', European Physical Education Review, 2 (2): 94–104.

Reid, A. (1997) 'Value pluralism and physical education', European Physical Education Review, 3 (1): 6–20. Siedentop. D. (1986) Sport Education. Champaign, IL: Human Kinetics.

Siedentop. D. (2002) 'Content knowledge for Physical Education', Journal of Teaching in Physical Education, 21 (4): 409–18.

Slote, M. (1989) Goods and Virtues. Oxford: Clarendon Press.

Standish, P. (1998) 'In the zone: Heidegger and sport', in M.J. McNamee and S.J. Parry (eds) Ethics and Sport. London: Routledge. pp. 256–69.

Strawson, P.F. (1959) Individuals. London: Methuen.

Thompson, K. (1983) 'The justification of physical education', Momentum, 2 (2): 19–23. White, J.P. (1990) Education and the Good Life. London: Kogan Page.

Whitehead, M. (1990) 'Meaningful existence, embodiment and physical education', Journal of Philosophy of Education, 24(1): 3–13.

Wollheim, R. (1993) The Mind and its Depths. London: Harvard University Press.

ALLMAN, B.L., and C.L. RICE. Neuromuscular fatigue and aging: Central and peripheral factors. Muscle and Nerve. 25:785-796. 2002.

BAHAMONDE, R.E. Changes in angular momentum during the tennis serve.Sports Sci. 18(8):579-592. 2000.

BEHM, D.G., K.M. BAKER, R. KELLAND, and J. LOMOND. The effect of muscle damage on strength and fatigue deficits. J. Strength Cond. Res. 15(2):255-263. 2001.

BLOOMER, R.J., and J.C. IVES. Varying neural and hypertrophic influences in a strength program. NSCA J. 22(2):30-35. 2000.

BOMPA, T. Periodization of Strength: The New Wave in Strength Training.Toronto, ON, Canada: Veritas, 1993.

CARPENTER, J.E., R.B. BLASIER, G.G. PELLIZZON. The effects of muscle fatigue on shoulder joint position sense. Am. J. Sports Med. 26(2):262-265. 1998.

CLARKSON, P.M., K. NOSAKA, and B. BRUAN. Muscle function after exercise-induced muscle damage and rapid adaptation. Med. Sci. Sports Exerc. 24(5):512-520. 1992.

COHEN, D.B., and M.A. MONT. Upper extremity physical factors affecting tennis serve velocity. Am. J. Sports Med. 22(6):746-754. 1994.

FORESTIER, N., N. TEASDALE, and V. NOUGIER. Alteration of the position sense at the ankle induced by muscular fatigue humans. Med. Sci. Sports Exerc. 34(1):117-122. 2002.

KAURANEN, K.L., T.S. PERTTI, and H.V. VANHARANTA. Strength training for 1h in humans: effect on the motor performance of normal upper extremities. Eur. J. Appl. Physiol. 79(5):383-390. 1999.

KENT-BRAUN, J.A. Central and peripheral contributions to muscle fatigue in humans during sustained maximal effort. Eur. J. Appl. Physiol. 80:57-63. 1999.

KIBLER, W.B. Biomechanical analysis of the shoulder during tennis activities. Clin. Sports Med. 14(1): 79-85. 1995.

MURAKAMI, Y. The effect of same-day strength training on ball velocity of division I female soccer players. Masters Thesis, Brigham Young University, Provo, 2002.

MYERS, J.B., and S.M. LEPHART. The role of the sensorimotor system in the athletic shoulder. J. Athl. Train. 35(3):351-363. 2000.

ROETERT, E.P., T.S. ELLENBECKER, D.A. CHU, and B.S. BUGG. Tennis- specific shoulder and trunk strength training. Strength Cond. 19(3):31-39. 1997.

ROONEY, K.J., R.D. HERBERT, and R.J. BALNAVE. Fatigue contributes to the strength training stimulus. Med. Sci. Sports Exerc. 26(9):1160-1164. 1994.

WOOLSTENHULME, M.T., B.K. BAILEY, and P.E. ALLSEN. Vertical jump, anaerobic power, and shooting accuracy are not altered 6 hours after strength training in collegiate women basketball players. J. Strength Cond. Res. 18(3):422-425. 2004