THE EFFECT OF TRAINING THROUGH A PARTIAL RANGE OF MOTION

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INTRODUCTION: Resistance exercise is fundamental for effective muscle functioning. It is valuable not only as a means of athletic conditioning, but also for rehabilitative and preventive programs. From the point of view of the rehabilitation specialist, specific knowledge with regard to aspects such as time constraints on healing, immobilization effects, specialized anatomy and exercise physiology benefits are vital for professional decision-making [Albert, 1993]. One issue of practical implication is training throughout a limited range of motion (ROM) during rehabilitation. It is often recommended that strength exercises be performed through a complete ROM in order to optimize the contraction-coupling process of actin and myosin within the muscle's sarcomers [Perrin, 1993]. However, rehabilitation frequently commences with resistance training (RT) through partial ROM (PROM) in cases where motion is limited by pain, joint stiffness, muscle weakness and in order to minimize the risk of re-injury. For example, the fact that patellofemoral joint reaction force is low at full extension explains why patients with patellofemoral joint derangement are able to perform exercises against resistance with less pain, providing that knee flexion is kept within 20° of full extension [Nordin & Frankel, 1980]. Another example is the case of rehabilitation after ACL reconstruction. There are indications that knee extension can be detrimental to the graft in the last 30°- 45° of knee extension due to increased anterior tibial translation, which causes high shear forces in the ACL graft [Tovin, et al., 1992]. However, during rehabilitation a major objective is to regain functional mobility of the lower extremity. This necessitates strengthening the knee extensors at full ROM. The obvious implications are that patients will either refrain from strengthening exercises until they regain mobility throughout a full ROM or may alternatively exercise through a restricted ROM. The first alternative is not a viable option when an accelerated program is required for a quick return to competitive form. The second alternative poses a question of whether RT at a PROM is specific to the training ROM or may it contribute to strength development outside the exercising ROM?

Studies on specificity of RT with regard to joint ROM based on isometric training and isometric testing support the contention that strength gains are greater at the angular position at which RT is conducted than at other positions (Morrisey et al., 1995). Some studies demonstrated that the effects of isometric training at particular joint angles are transferable up to 20º outside the training position [Knapik et al. 1983, Kitai and Sale, 1989]. In contrast with these findings, Marks (1994) reported that isometric training in the midrange may be sufficient to strengthen the extensors surrounding an osteoarththritic knee through a wider range of motion. Data regarding the specificity of PROM in dynamic RT are scarce. Graves et al. (1989) found some isometric strength gains at angles outside the PROM RT, performed through one half of the ROM. In a later study, Graves et al.

(1992) found that training of the lumbar extensors through a 36° ROM is effective in developing isometric strength through 72° of lumbar extension. Nowadays, isokinetic muscle evaluation and RT are very popular in rehabilitation protocols. No data was found in the literature regarding the ROM specificity in isokinetic exercise. The purpose of this study was to examine the effect of PROM isokinetic RT of the knee flexors on strength throughout the full ROM.

METHODS: Four physical education students volunteered for this study. All subjects had no history of knee injury. Right leg strength for flexion and extension through the knee joint was measured by a Cybex II isokinetic dynamometer (Division of Lumex, Inc., BayShore, NY.), interfaced with a microcomputer. Each subject reported to the laboratory for two testing sessions, one week before initiation of the training program and after completing six weeks of isokinetic RT. The training period was divided into two sub-periods of three weeks each. During the first sub-period the subjects trained three times a week with at least 48 hour intervals. They performed three sets of ten repetitions each with one minute break between sets. The training velocity was $60°.sec^{-1}$ and the PROM was 40º to 70º. The subjects were instructed to perform both flexion and extension at maximal effort with an emphasis on the flexors. During the second sub-period subjects trained three times a week performing three sets of fifteen repetitions each with one minute break between sets. During the six weeks of RT subjects were instructed to refrain from any physical activity that might influence the development of leg strength.
Pre-training and post-training tests included 5 consecutive cycles of knee extension and flexion at $60°.sec^{-1}$ at a ROM of 5°- 85°. The last 4 trials were used for analysis. The full ROM was divided into three sectors: 5°-40°, 40°-70°, 70°-85°. Total work outputs through each of the sectors were computed separately. The size effect of the changes in strength was evaluated in two ways: a) The percentage changes relative to the pre-training values, and b) The ratio between the mean gain and the pre-training standard deviation (s.d). The work output of each sector was subjected to a two way ANOVA (4 trials by pre-post).

RESULTS: Results are displayed in Table 1.

Table 1: Changes from Pre to Post – training in work outputs (Joules).

ROM (°)	Pre-test (mean±s.d)		Post-test (mean±s.d)		Size effect ?(J)/s.d(J)	change %
5-40	24.91	±7.00	32.26	±5.86	1.05	29.50
40-70	24.77	±6.50	31.35	±7.76	1.01	26.56
70-85	8.47	±2.46	10.13	±2.46	0.67	19.60

The post-training gains in strength, were statistically significant ($p<.05$) in all three sectors. The mean strength gain in the trained ROM was 26.6% or 1.01 s.d. The strength gain in the more extended ROM was quite similar (29.9% and 1.05 s.d). In the more flexed ROM the strength was slightly lower (19.6% and 0.67 s.d). Neither trail effects nor interaction effects were significant.

DISCUSSION: The current results are based on repeated measures of four healthy subjects. The repeated measures secure the reproducibility of the gain effects over several trials. The use of an ANOVA procedure with such a small sample is not fully compatible with the theoretical assumptions of normality and of homogeneity of variance underlying such a procedure. Nevertheless, this statistical test is considered to be robust to violations of the above mentioned assumptions. The statistical significance in this case is surprising since it is based on a limited number of degrees of freedom. Furthermore, the statistical test is substantiated with quite sizable effects. However, caution in the interpretation of these results is necessary with respect to their generalization to the whole population and to training effects among injured subjects.

Within the limitation of the current sample, the hypothesis of specific local effect of RT should be rejected. RT through a PROM elicited substantial strength improvement through full ROM in all four subjects.

Previous research on ROM specificity was based on isometric RT and on isometric testing. Under such conditions a ROM specificity or very limited transfer of strength gain were documented. In those studies the training period was relatively short, lasting 8 – 10 weeks [Knapik, 1983; Bandy and Hanten, 1993]. One exception is the work of Marks [1994], who demonstrated transfer of strength gain beyond the isometric PROM that was used for RT after a training period of 16 months. Transfer outside the training ROM was also observed with isometric testing after dynamic RT of the lumbar extensors which lasted 12 weeks [Graves, 1992]. The current results procedure is unique in that both training and testing were conducted isokinetically. The results suggests that transfer from PROM to the full ROM may be accomplished within a relatively short training period of 6 weeks.

Neural adaptation has an important role in RT, especially during the first several weeks [Sale, 1991]. The transfer of strength to the extended ROM may be attributed to such adaptation. In a dynamic task, RT may involve learning, i.e., the firing of a number of motor units in a specific sequence may be coordinated to achieve maximal force. In the current study, the PROM during RT was 30º and the angular velocity was $60º.sec^{-1}$. This combination allows 0.5 second for force development. This is a longer period of time than the minimum required for maximal tension development. Thus, the current training protocol provided sufficient time for the learning of motor unit recruitment for dynamic tension development. It is possible that this recruitment pattern was transferable to dynamic contraction outside the training zone. From this point of view, it may be hypothesized that a combination of PROM and angular velocity should allow sufficient time for the development of maximum tension in order to elicit substantial training effects outside the PROM.

Intuitively, the current observations lead to a recommendation to employ PROM RT in rehabilitation protocols in order to gain dynamic strength through the full ROM. However, final conclusions in this regard should await further investigations based on larger samples of injured populations.

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