SHORT RANGE OF MOTION ISOKINETIC EXERCISE: REHABILITATION IMPLICATIONS

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The study explored transferability of short ROM isokinetic conditioning inside and outside the trained ROM. 55 women were randomly assigned to 4 groups: 1 & 2 trained concentrically at 30 & 90°/s respectively, 3 & 4 trained similarly but eccentrically. All groups trained within 30-60° of knee flexion, 4*10 rep, 3 * week * 6 weeks. Isokinetic work output (Wisk) was assessed pre and post training within 3 ROM's: 85-60°(R1), 60-30°(R2), and 30-5°(R3). Isometric peak moment (PM) and rate of force development (RFD) were evaluated at 10°, 45° and 80°. Significant increases in Wisk (R1 and R2), isometric PM (all 3 angles) and RFD (45°) was exposed. These findings point to potential rehabilitation benefits, leaning on initiating strength training prior to regaining full ROM.

KEY WORDS: specificity of training, comparative study.

INTRODUCTION: Sport joint injuries very often result in restricted range of motion (RoM), stiffness and muscle atrophy leading to limitations in athlete mobility (Tovin et al, 1992). Therefore, rehabilitation is aimed at regaining full RoM and recovery of muscle performance. However, elements like joint loads and the duration of exposure to such loads are critical factors (Dvir et al, 2001). With respect to the particular training protocol, the specificity topic is of supreme importance. The so-called transfer of training namely the extent to which one training modality or system results in significant improvement in another. These instances include strength benefits gained from the concentric (Con) into eccentric (Ecc) mode, from low speed into high speed, from isometric into dynamic, from the trained limb into the contra-lateral - untrained limb, etc. However, relatively little is known regarding the effect of training using short RoM on muscle performance outside the trained range. Normal dynamic voluntary muscular contraction involves all the neurophysiological mechanisms taking part in generating force. This applies equally regardless of the RoM (Komi, 1992: McComas, 1996). Using isometric conditioning a number of studies indicated that angular specificity ranged up to 22° (Morrisey, 1995). Graves et al (1992) applied dynamic training of the knee and lumbar extensors using RoMs of 22° and 36°, respectively. As only isometric data was collected, no dynamically-based performance variables, which reflect functional factors in sports activities could be derived. If strength conditioning within limited RoM can be shown to be transferable outside the trained range, such a method would have a distinct advantage. For instance, in athletes with impaired anterior cruciate ligament (ACL (a bilateral deficit of 20% to 30% in quadriceps strength has been observed (10, 21). However, athletes who have undergone reconstruction of impaired ACL should not subject their quadriceps to progressive resistive exercise within the 0-30o of knee flexion in order to avoid excessive shear forces that may endanger the graft (Albert, 1993: Tovin et al, 1992). On the other hand, this very range is of prime importance form the functional point of view in most sport activities. Hence, the use of short ROM training, outside the risk zone as well as (in other cases) the painful arc is an intriguing option.
Therefore the main objective of the present study was to examine the transferability of short RoM performance gains into a larger (heretofore, 'full') RoM.

METHODS: Fifty-five young healthy PE women without previous knee injuries students volunteered to take part in this study. They were randomly divided into four experimental groups: 1 n =14 , age =23.8 ± 1.2yr: ht = 167.3 ± 5.6 cm: wt= 56.7 ± 8.8 kg, 2 n = 14:

age= 23.6±1.3 yr: ht= 162.4± 5.8cm: wt= 53.9± 4.1kg, 3 n= 13: age=23.2±1.9yr: ht= 165.3 ± 7.0cm: wt= 56.5± 6.9 kg, 4 n= 14: age= 23.4 ±1.2 yr: ht =165.8 ± 5.3cm: wt = 58.8± 7.0 kg. None of the subjects participated in any professional muscular exercise during the study. Subjects were excluded from the study if they reported any pain during exercise or tests.

Design: Pre and post training strength tests: Uniform tests were conducted 1 week before the training sessions (pre test) and 2 days after termination of the training period (post test) on the dominant leg (51R and 4L). The tests as well as the training were performed using a Biodex System II (Biodex Corp., Shirely, NY) isokinetic dynamometer. Prior to the test each subject underwent the following procedures. The lateral femoral and tibial condyles were identified and marked. The space between these points was marked and considered as the sagittal axis of the knee joint. Subjects were stabilized in a seated position using Velcro straps for the thighs, with the hip joint at 110°, the axis of the knee joint aligned with the axis of motor, and the distal pad of the lever arm attached with Velcro straps 5cm proximal to the lateral malleolus. Subject were instructed to reach a full extension (0° of the knee joint) and the test RoM was then adjusted to span 5-85o of knee motion. The choice of five degrees as the final extension angle was due to the need to successfully generate the required Ecc contractions. Prior to each test subjects underwent a warm up of 18 consecutive knee extensions as follows: 10 sub-maximal rep at 90o/s, five sub-maximal rep at 60o/s and two sub-maximal rep at 30o/s. After 1 min of rest, subject were asked to generate one maximal knee extension at 30°/s. Isometric quadriceps extension strength assessment was based on 3 maximal rep performed at 45, 80 and 10° of knee flexion. Each contraction lasted 3s with an inter-contraction and inter-angle rest of 4s and 1 min, respectively. Following a rest period of 5 min isokinetic knee extension tests followed consisting of five maximal Con rep at 30°/s and 90°/s, respectively and an identical protocol for the Ecc contractions. The inter-velocity rest was 5 min. All strength values were corrected for the effect of gravity.

Training: Group 1 trained Con at 30°/s over a RoM of 30° located between 30-60° of knee extension. Group 2 trained Con at 90°/s but otherwise similar to 1. Group 3 trained Ecc but otherwise similar to G1. Group 4 trained Ecc but otherwise similar to Group 2. Subjects trained 3 times per week (48 hours interval) for 6 weeks. Each session consisted of 4 sets of 10 maximal consecutive contractions of the knee extensors with 1 min interval between sets.

Assessment: The work (W) output of the knee extensors was evaluated from three RoM's at the knee joint: R1 = 85-60°, R2 = 60-30°, R3 = 30-5° and was expressed in Joules. The isokinetic and isometric peak moments (PM) were expressed in Nm. The rate of force development (RFD) of the knee extensors was calculated as followed: RFD (N/s) = (90%PM-10%PM) / (tPM2 - tPM1) where N is Newton units, s is second, and tPM2 and tPM1 are the time duration till 90% and 10% of the peak isometric moment respectively.

Analysis Methods: The last 4 isokinetic and all 3 isometric moment curves were used for statistical analysis. For each subject, mean and standard deviation of the dependent variables were calculated (pre and post training tests). Paired Sample Tukey T-Test pre and post training was used at all subjects for all testing modes. Multiple analysis of variances (MANOVA) with repeated measures on the time scale (pre and post training tests) was used to reveal significant interaction between different testing and training conditions within and in between experimental groups. The level of statistical significance was set at $p < 0.05$.

RESULTS: Across group findings: At all experimental groups work output at ROM R1 (untrained outer RoM) increased more (but not significantly) than in R2 - the trained ROM.

In contrast, despite a general increase in work within R3 (inner RoM), this change was non-significant. Post hoc analysis revealed a significantly greater gain in work values at ROM's R1 and R2 compared to R3, with no clear tendency towards either the concentric or eccentric testing modes. These results suggest transferability of gains from the middle RoM towards the outer RoM but not to the inner RoM. There was no clear advantage towards any contraction mode or training velocity. Isokinetic pre and post training knee extension peak moments showed a significant increase in all experimental groups. A higher increase occurred when testing and training conditions were similar e.g. training eccentrically at 30°/s a nd testing for

gains at the same velocity. This phenomenon occurred in all experimental groups and testing modes, except two (out of 16) cases. Isometric PMs pre and post training indicated a significant increase at all joint angles. These results included the 80° and 10° joint angles that were located in the untrained RoMs. Similar to the isometric PM findings, the RFD changes revealed uniform and significant increases in tests that were conducted at 45° (mid trained RoM), at all experimental groups. Post hoc analysis demonstrated a significantly greater RFD increase when tests took place at 45° compare to 10°.
Between group findings: Significant interaction between experimental groups was revealed in isokinetic PM evidencing different gains of isokinetic PM at different groups. Further analysis pointed out that the source for this interaction was due to a significantly greater increase of Ecc PM at group 3 and 4 compared to group 1 and 2.

DISCUSSION: Knee injuries are often characterized by a severe drop in the cross sectional area (CSA) of the quadriceps muscle and an acute loss of strength (Tovin et al, 1992). This muscle is considered pivotal to various sport activities. To counteract these effects, clinicians encourage athletes to return to normal activity as fast as possible (Morrissey, 1995). Nevertheless, high shear forces around the knee joint during resistance training should be noticed while conducting any rehabilitation program, especially following surgical intervention (Tovin et al, 1992). These facts lead to one of two options: 1. Preventing muscle strengthening until regained full RoM. 2. Initiating strength training at partial RoM. The second possibility begs the question whether such an approach will result in functional gains outside the trained RoM or will it be specific only to the trained RoM. The main outcome of this study is that significant increase in work output might be achieved outside the trained RoM. This major finding was valid both to Con and Ecc conditioning, equally in terms of relatively short ('high' velocity) and long ('low' velocity) movement durations and thus occurred at all experimental groups. Exploring RoM specificity few studies indicated significant transfer of isometric strength spreading up to 22 and 32 degrees away from the trained RoM (Graves et al, 1992: Knapik et al, 1983: Kaufman et al, 1991). In these studies, despite the significant increase in the isometric PM outside the trained RoM, the improvement inside the trained RoM was, as expected, more remarkable. In contrast to these findings in the present study, increases in work output outside the trained RoM were noted particularly with respect to outer RoM (85-60°). The latter being consistently greater, albeit non-significantly, than those achieved in the trained RoM. What mechanism could explain the transfer of dynamic functional gains into an untrained RoM? While generating positive (Con) or negative (Ecc) work, beside enlargement of contractile properties (Actin and Myosin), changes in muscle length against resistance lead to a greater improvement in muscle work output compare to static contractions (Morrissey, 1995). This phenomenon occurs due to the large differences between the motor patterns of dynamic versus static contractions e.g. muscle group coordination (agonist/antagonist) (Sale, 1991), increased active motor unit (MU) pool, amplitude and frequency of operation (komi, 1992), increase in muscular RFD and a decrease in the antagonist moment (McComas, 1996). The crucial time duration for generating maximal strength last approximately 0.3s (Komi, 1992). Thus, in order to generate maximal muscular moment within a short ROM, low velocities may be preferable. These facts dictated us the training paradigm consisting of 30°/s and 90°/s using a ROM of 30°. The combination of these velocities RoM resulted a nominal movement time of approximately 1.0 and 0.33s respectively. Although the movement was executed in a different RoM (training vs. testing), while shortening or lengthening these fibers, actually manifested the same adaptation. The above may explain the meaningful transfer of work values outside the trained RoM as well as the transfer of isometric PM towards 80 and 10° in the present study. Furthermore, the findings point out to a low RoM specificity (transferability of strength between different RoM) as well as to low specificity of contraction mode (from dynamic to isometric mode of contraction) despite the fact that training took place at a short RoM. Despite the general improvement in work output at the inner RoM, the increase in this RoM was not significant. Work gains were obtained more in the outer (8.3%) compare to the inner (26.1%) RoM (sig.), at all experimental groups. This phenomenon differs from that which characterized isometric paradigms that indicates bi-directional transfers. A possible explanation could lean on evidences that greater synthesis of Actin and Myosin molecules take place while muscle underwent static or dynamic stretching compare to shortening and may be related to the synthesis of protein molecules (Seger, 1998). Another possible explanation could be that the shape of a dynamic moment curve is affected by biomechanical factors such as the muscle force vector. 60° of knee flexion are known to be the quadriceps muscle "optimal angle". In the present study that angle tangent the outer range (85-60°), and thus the significant increases in the isokinetic PM can explain, at least partly, the greater increase in work and isometric values at the outer RoM. In addition, a relatively high increase in RFD was observed at 80 and 10° although in few cases failed to reach significance. The area under a moment curve is the sum of the accumulated moments during the entire RoM. A steeper RFD slope affects the moment curve shape mostly at the beginning of the dynamic contraction, causing an increased moment curve slope, providing greater work values (Sale, 1991). This explanation is coordinated with the present study findings as there was a uniformly greater increase both in RFD and in work output at ROM R1 (85-60°) for all experimental groups.

In conclusion, this study indicates that isokinetic conditioning within a restricted RoM has a functional value inside and outside the trained RoM causing a significant increase in work values. Most changes occurred at the trained RoM and when muscle is at its lengthened position (outer RoM), but not when muscle was trained at its shortened position. Eccentric mode was more specific than its concentric counterpart, causing a higher tendency of PM increase. Both contraction modes were less specific in terms of the isometric mode. No superiority of any mode of contraction or velocity was found related to the increase in work values. These findings may lead to novel rehabilitation and training programs, leaning on initiating strength training prior to achieving a full RoM. However, the present study focused on the knee joint of healthy subjects. In order to use similar rehabilitation procedures in clinical cases, further studies involving a diversity of joints, a variety of RoMs and specific clinical groups should be conducted.

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