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Original Research

Comparison of Controlled Articular Rotations and Static Stretching on Hip Internal Rotation Range of Motion

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Abstract

International Journal of Exercise Science 19(3): 3005, 2026. Range of motion (ROM) deficits of the hip can contribute to many musculoskeletal dysfunctions throughout the body. Specifically, lack of hip internal rotation (IR) ROM has been correlated with increased likelihood of anterior cruciate ligament injury, fall risk, low back pain, and upper extremity injury. Controlled Articular Rotations (CARs), a form of dynamic stretching, has gained popularity as a treatment strategy for improving joint ROM. The purpose of this study was to compare the acute effects of the CARs protocol and static stretching (SS) on hip IR ROM in a young adult population with limited hip mobility. Twenty-eight young adults (13 M; 15 F) aged 21-26 years completed the study. Exclusion criteria included hip IR passive ROM (PROM) >35 degrees or history of hip pathology/surgery. Participants were randomized into a CARs group or SS group. Hip IR ROM was measured prior to the performance of the stretching program, immediately post-intervention, and 15-minutes post-intervention. A 2x3 repeated measures ANOVA revealed no significant group x time interaction ($p=0.193$) and no significant main effect of group ($p=0.536$). However, there was a significant main effect of time ($p<0.001$). Post-hoc comparisons showed significant increases in ROM from pre- to immediate post-intervention ($p<0.001$) and from pre- to 15-minutes post-intervention($p<0.001$), with no significant difference between immediate post- and 15-minutes post-intervention ($p=1.00$). These results support the use of both SS and CARs as effective interventions to improve hip IR ROM.

Keywords: Dynamic stretching, stretching, static stretching, hip internal rotation, range of motion

Introduction

Range of motion (ROM) deficits of the hip can contribute to musculoskeletal dysfunctions throughout the body. Lack of adequate hip internal rotation (IR) ROM has been shown to increase the likelihood of anterior cruciate ligament injuries, fall risk, low back pain, and even upper extremity injuries in baseball pitchers.[1–7] One potential cause of hip IR ROM deficits may be limited flexibility of muscles that cross the affected joint, specifically the hip external rotator (ER) muscles.[8] These muscles include the gluteus maximus, piriformis when the hip is positioned in less than 90 degrees of hip flexion,[9] superior gemellus, inferior gemellus, obturator internus, obturator externus, and quadratus femoris. The iliopsoas, while primarily considered to be a hip flexor, also plays a small role in hip ER due to its insertion point on the lesser trochanter of the femur.[10]

Stretching is a common intervention utilized by rehabilitation professionals to improve ROM when deficits are thought to result from impaired muscle flexibility.[11,12] Two types of stretching

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commonly used in clinical practice include static stretching and dynamic stretching. Static stretching involves maintaining a lengthened position of the target muscle to a point where a stretch sensation is reached.[13] Numerous studies support the effectiveness of static stretching for increasing ROM.[12–14] Dynamic stretching involves repeated, controlled active movements through the full ROM of a joint via contraction of the agonist muscles. This allows elongation of the antagonist (target) muscles without holding the stretch in the end-range position.[14] Dynamic stretching has also been shown to be effective in increasing joint ROM.[15,16] Both static and dynamic stretching have been shown to improve hip IR ROM.[8,15,17,18]

Controlled Articular Rotations (CARs), a form of dynamic stretching, has gained popularity among fitness and rehabilitation professionals as a treatment strategy for improving joint ROM. The concept of CARs is promoted through the Functional Range Systems™ approach, created by Dr. Andreo Spina. This form of stretching utilizes slow, controlled, active rotational joint motions performed at the outer limits of a joint's available ROM. The goal is to move the joint through its full, pain-free ROM in all directions, and through all planes of motion. While typical dynamic stretching involves the use of swinging the limb or momentum to create a stretch, CARs utilize controlled, intentional movements. Despite its growing popularity, empirical evidence supporting the effectiveness of CARs is limited. To date, no studies have examined the effect of CARs on joint ROM. Therefore, the purpose of this study was to compare the acute effects of static stretching and CARs on hip IR ROM in a young adult population with limited hip mobility. We hypothesized there would be no significant difference in hip IR ROM between the two stretching interventions.

Methods

Participants

The current study was approved by a University Institutional Review Board. This research was carried out fully in accordance to the ethical standards of the *International Journal of Exercise Science*.[19] Prior to initiating the study, all participants read and signed an informed consent document. All data collection was performed during a single test session on the University's campus.

An *a priori* sample size calculation was conducted using G*Power software 3.1.9.4 (Universitat Kiel, Germany). Based on a moderate effect size (f=0.25), an alpha level of 0.05, and a desired statistical power of 0.80, a total of 28 healthy adults (13 males; mean age=23.5 years) were recruited from the University using convenience sampling. Inclusion criteria included males or females aged 18-26 years with <35 degrees of hip IR ROM on at least one hip. Normative values for hip IR have been reported to range from 35 to 45 degrees.[20–22] Exclusion criteria included a history of hip injury within the previous 3 months or any history of hip surgery or diagnosed hip pathology (e.g. femoral acetabular impingement or labral pathology).

Protocol

This study used a 2x3 repeated measures design to compare the acute effects of static stretching and CARs on hip IR ROM. The independent variables included type of stretching protocol [static stretching (SS) and Controlled Articular Rotations (CARs)] and time [pre-intervention (T1); immediately post-intervention (T2); and 15 minutes post-intervention (T3)]. The dependent variable was hip IR ROM.

All participants completed a standardized questionnaire to collect demographic and health history information. Following this initial screening process, all eligible participants underwent ROM assessment for hip IR ROM on both hips. Participants were asked to remove their shoes and were positioned seated on the edge of an examination table with both legs hanging over the edge of the table (hips and knees flexed to ~90 degrees) and weight equally distributed over both ischial tuberosities. A folded towel was placed under the thigh of the hip to be measured to position the femur in the horizontal plane.

Investigator-1 (I-1) passively moved the hip to the end range of hip IR, as determined by the point of tissue resistance. I-1 maintained the limb position while Investigator-2 (I-2) aligned the goniometer for ROM measurement. Measurements were obtained and read aloud by I-2 and recorded onto a data collection spreadsheet by I-1. All ROM measurements were taken by the same investigator (I-2) using a standard 12-inch Baseline® plastic goniometer (Fabrication Enterprises, Elmsford, NY, USA) with the measurement protocol described by Reese and Bandy (Figure 1).[20] I-2 was blinded to group assignment.

Figure 1. Measurement of hip IR ROM.

Participants meeting the ROM inclusion criterion on at least one hip following the baseline measurement (T1), were randomized to either the SS group (*n*=14) or the CARs group (*n*=14) using an online randomizer program. If both hips met the inclusion criteria, the hip with the least amount of IR ROM was used for the study. Investigator-3 (I-3) instructed each participant in the designated stretching exercise protocol, based on the group assignment. All stretching exercises were verbally explained to the participant, followed by a demonstration of the exercises by the investigator. Exercises were supervised by I-3 to ensure proper technique and were performed in an area separated from the data collection area. This was done to ensure blinding of the measuring investigator (I-2) to group assignment during assessment of post-intervention hip IR ROM.

The SS exercise protocol consisted of a modified lunge stretch (Figure 2), supine figure-4 stretch (Figure 3), and supine adduction piriformis stretch (Figure 4). These stretches are commonly used in the clinical setting and target muscles that have been identified as hip external rotators.[8] Each stretch was held for 30 seconds and performed for 4 repetitions, with a 10-second rest period between repetitions.

Figure 2. Modified lunge stretch.

Figure 3. Supine figure-4 stretch.

Figure 4. Supine adduction piriformis stretch.

The CARs exercise protocol consisted of a standardized dynamic stretching program in which participants performed slow, controlled circular hip movements through the available ROM, while attempting to reach the end range of motion in each direction (Figure 5). The protocol consisted of two 1-minute bouts separated by a 20-second rest period.

Figure 5. Controlled articular rotations through available hip ROM.

Immediately following completion of the assigned stretching protocol, each participant returned to the data collection area for a ROM measurement (T2). Participants were then seated for a 15-minute rest period, followed by the final ROM measurement (T3). Post-intervention ROM measurements were taken utilizing the same procedures as described for the baseline measurement.

Statistical Analysis

Measures of central tendency and variability were used to describe participant demographics (Table 1). Normality of data distribution was assessed using the Shapiro-Wilk. A 2x3 repeated measures ANOVA was performed to examine differences in hip IR ROM between groups across time, and to evaluate the group x time interaction. The between-subjects factor was group (SS and CARs), and the within-subjects factor was time (pre-intervention, immediate post-intervention, and 15-minutes post-intervention). Mauchly's Test was used to test the assumption of sphericity.

When a significant main effect was observed, post-hoc pairwise comparisons with Bonferroni adjustment were conducted.[24] The level of statistical significance was set at $p \leq 0.05$. Effect sizes were calculated using the partial eta squared coefficient and interpreted as small (0.01), medium (0.06), and large (0.14).[25] All statistical analyses were performed using SPSS version 28.0 (IBM Corp., Armonk, NY, USA).

Table 1. Means, standard deviations (SD), and percentage distributions of demographic variables.

Demographic Variable	Mean (SD)	Percent (n)
Age (yrs)	23.5 (1.1)	--
Height (in)	68.7 (2.7)	--
Weight (lb)	172.7 (28.2)	--
Gender (% male)	--	46.4 (13)
Hip (% left)	--	60.7 (17)

Results

Shapiro-Wilk and Mauchly's tests were non-significant ($p>0.05$) indicating that assumptions of normality and sphericity were not violated. Means and standard deviations for hip IR ROM at pre-intervention (T1), immediate post-intervention (T2), and 15-minutes post-intervention (T3) are presented in Table 2.

Table 2. Means and standard deviations for hip IR ROM.

ROM Measurement	SS Group	CARs Group
T1	26.4 (3.9)	28.6 (4.0)
T2	33.2 (5.9)	33.6 (4.4)
T3	32.7 (4.8)	32.9 (3.5)

A 2x3 repeated measures ANOVA revealed no significant group x time interaction ($F(2,52)=1.69$, $p=0.19$) and no significant main effect of group ($F(2,52)=0.393$, $p=0.54$). There was, however, a significant main effect of time on hip IR ROM ($F(2,52)=54.06$, $p<0.001$, $\eta^2 p=0.68$), demonstrating a large effect size. Post-hoc pairwise comparisons indicated that hip IR ROM increased significantly from pre-intervention to immediately post-intervention ($p<0.001$) and remained elevated at 15-minutes post-intervention ($p<0.001$). No significant difference was observed between the two post-intervention measurements ($p=1.00$).

Discussion

The purpose of this study was to compare the acute effects of SS and CARs on hip IR ROM in young adults with limited hip mobility. It was hypothesized that no significant difference in hip IR ROM would be observed between the two stretching interventions. The results of the study support this hypothesis. While significant increases in ROM were seen over time, the improvements occurred regardless of group assignment. These findings suggest that SS and CARS are similarly effective in producing short-term improvements in hip IR ROM.

These findings are consistent with previous literature demonstrating that both static and dynamic stretching interventions can improve joint ROM. SS has been extensively studied and shown to be effective for increasing joint mobility.[14,26–28] Recent meta-analyses by Shah et al[28] and Takeuchi et al[12] further support the use of acute SS for improving ROM. Dynamic stretching (DS) has also been shown to be effective for enhancing joint mobility.[13,15,29–31] However, studies comparing SS and DS have reported conflicting results regarding their relative effectiveness. Several investigations have found no significant differences between the two approaches,[29,32–35] whereas others have reported greater improvements with DS.[36,37] In contrast, a meta-analysis by Konrad et al concluded that SS may produce greater ROM gains than DS.[27] While no previous studies have specifically examined the effect of CARs on joint ROM, CARs can be conceptually categorized as a form of dynamic stretching. As such, the lack of difference observed between groups in the present study is consistent with the mixed findings reported in the literature comparing SS and DS interventions.

The retention of hip IR ROM gains at 15-minutes post-intervention are also consistent with previous studies. Hubley et al demonstrated that static stretching and stationary cycling were equally effective for increasing hip flexion and extension ROM and retaining the ROM gains for a 15-minute period of inactivity.[38] Iwata et al reported increased passive knee extension ROM following DS of the hamstrings with ROM gains maintained for 90 minutes post-intervention.[30]

The absence of a difference between groups may be explained by shared underlying mechanisms through which both SS and CARs influence joint ROM. Shah et al[28] and Takeuchi et al[12] suggest that acute improvements in ROM following SS are primarily attributed to an increase in stretch tolerance, as well as reduced muscle-tendon unit (MTU) mechanical properties (e.g. decreased stiffness of muscle and connective tissues). Iwata et al proposed similar mechanisms for improved joint ROM when examining the effects of DS on hamstring flexibility and knee extension ROM.[30] The sustained gains in hip IR ROM at 15-minutes post-intervention are potentially due to these same mechanisms.[30,39]

While the mechanisms appear similar, the physiological basis for the reduced MTU stiffness may differ between stretching interventions. During SS, reductions in MTU stiffness are thought to be related to the viscoelastic stress relaxation that occurs when the muscle is held in a static, lengthened position.[40–42] In contrast, reductions in MTU stiffness during DS are likely associated with increasing muscle temperature that occurs as a result of repeated, active contractions. Increased temperature may reduce the viscous resistance of the muscles, thereby enhancing tissue extensibility.[43–45] Given that CARs involve repeated, controlled active movement at end-range, it is plausible that they produce similar increases in stretch tolerance and temperature-mediated reductions in MTU stiffness, which may explain the comparable improvements in ROM observed between groups.

The current study is not without limitations. First, the study examined only a single session of the stretching interventions. It is therefore unclear whether similar results would be observed following repeated or long-term application of the stretching protocols. Second, while the study focused on participants with limited hip IR ROM, the sample consisted of young adults with a mean age of 23.5 years. This may limit generalizability to other populations, including children, adolescents, and older adults. Finally, although efforts were made to standardize performance of the stretching interventions, variation in participant effort, as well as variation in movement quality during the CARs may have influenced the results.

Future research should investigate the long-term application of CARs on joint ROM and explore the impact of CARs on functional performance measures. Additionally, studies should compare CARs to other mobility interventions across different clinical populations, such as individuals with femoroacetabular impingement or low back pain. This would help to further clarify the role of CARs in rehabilitation and performance settings.

In conclusion, the findings of this study have several important clinical implications. Both SS and CARs resulted in significant short-term improvements in hip IR ROM. These results suggest that clinicians may select either intervention when the goal is to acutely increase hip IR, allowing flexibility in exercise prescription based on patient preference or tolerance. Additionally, CARs may provide an alternative to traditional SS for individuals who prefer active movement-based interventions. Given that improvements were maintained at 15-minutes post-intervention, either stretching approach can be utilized shortly before activities requiring greater hip mobility.

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