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Comparison of two stretching methods and optimization of stretching protocol for the piriformis muscle☆

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ABSTRACT

Piriformis syndrome is an uncommon diagnosis for a non-discogenic form of sciatica whose treatment has traditionally focused on stretching the piriformis muscle (PiM). Conventional stretches include hip flexion, adduction, and external rotation. Using three-dimensional modeling, we quantified the amount of (PiM) elongation resulting from two conventional stretches and we investigated by use of a computational model alternate stretching protocols that would optimize PiM stretching.

Seven subjects underwent three CT scans: one supine, one with hip flexion, adduction, then external rotation (ADD stretch), and one with hip flexion, external rotation, then adduction (ExR stretch). Three-dimensional bone models were constructed from the CT scans. PiM elongation during these stretches, femoral neck inclination, femoral head anteversion, and trochanteric anteversion were measured. A computer program was developed to map PiM length over a range of hip joint positions and was validated against the measured scans.

ExR and ADD stretches elongated the PiM similarly by approximately 12%. Femoral head and greater trochanter anteversion influenced PiM elongation. Placing the hip joints in 115° of hip flexion, 40° of external rotation and 25° of adduction or 120° of hip flexion, 50° of external rotation and 30° of adduction increased PiM elongation by 30–40% compared to conventional stretches (15.1 and 15.3% increases in PiM muscle length, respectively).

ExR and ADD stretches elongate the PiM similarly and therefore may have similar clinical effectiveness. The optimized stretches led to larger increases in PiM length and may be more easily performed by some patients due to increased hip flexion.

1. Introduction

Piriformis syndrome (PS) is an uncommon and controversial clinical diagnosis for a non-discogenic form of sciatica [1–4]. The condition is characterized by deep pain in the buttock that may radiate to the lower back and posterior thigh of the affected leg. PS is not well defined and the lack of reliable diagnostic tests makes it primarily a diagnosis of exclusion [4]. The pathophysiology of PS remains uncertain. The etiology of PS is probably attributable to the intimate relationship of the piriformis muscle (PiM) and sciatic nerve [5]. Overuse or trauma may result in an inflamed or hypertrophic PiM that compresses the sciatic nerve as it exits the pelvis through the greater sciatic foramen [1]. The conservative treatment for patients diagnosed with PS has traditionally focused on stretching the PiM [6]. Stretching has two purposes: to increase the resting length of the tight PiM and to decrease the potential sciatic compression resulting from PiM tightness. PiM relaxation after stretching has been explained using the concepts of reciprocal inhibition and post-isometric relaxation [4,7,8]. Reciprocal inhibition is the automatic motor neuron inhibition that occurs in antagonist muscles [9]. Reciprocal inhibition has been implicated in the pathogenesis of PS: inactive gluteal muscles lead to overactive hip flexors, reciprocal inhibition of these gluteal muscles, and overuse, tightness, and hypertrophy of the PiM. Reciprocal inhibition has also been suggested as a management strategy for PS: the internal rotators (gluteal muscles) are contracted without allowing hip internal rotation and, after relaxation, the PiM is passively

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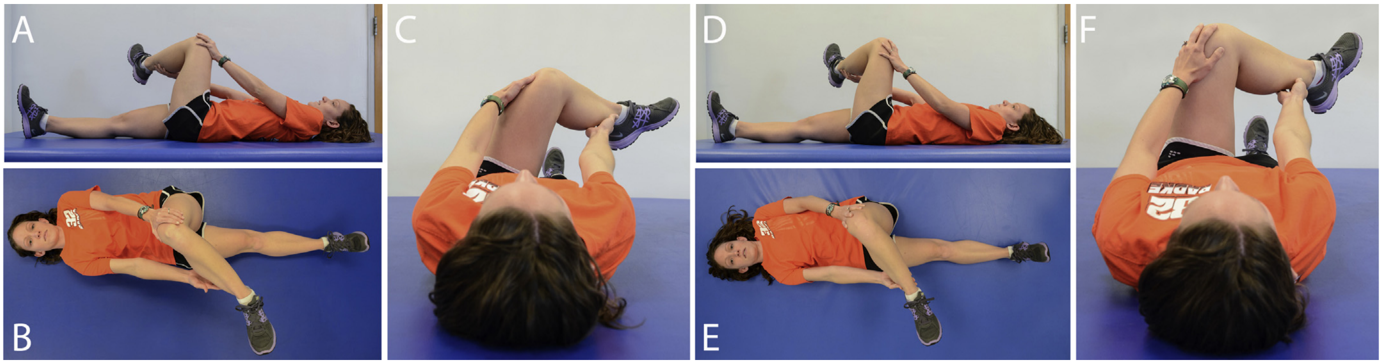

Fig. 1. Lateral (A and D), frontal (B and E), and proximal views (C and F) of a subject stretching her PiM. On the left (A–C), the femur is flexed at 90°, adducted, then externally rotated (ADD stretch). On the right (D–F), the femur is flexed at 90°, externally rotated, then adducted (ExR stretch).

stretched [8]. Post-isometric relaxation is achieved by bringing the painful PiM to maximal length without stretching, by an isometric contraction with minimal force, followed by relaxation with gentle PiM stretch [7]. PiM stretching is typically performed standing or in a supine position, and may include a combination of knee and hip flexion, hip adduction, and internal or external rotation of the thigh [6,10]. Little is known about the PiM elongation that result from these stretches and whether the effectiveness of these stretches is influenced by variations in femoral anatomy.

The objectives of this study were to compare the PiM elongation resulting from two conventional stretching protocols and to investigate alternate stretching protocols that would optimize PiM elongation. To achieve these objectives, we performed CT scans of a small group of subjects who stretched using two protocols, imported these CT scans into modeling software programs, and developed and validated a computational model of PiM elongation which could map PiM length over a range of hip joint positions and maximize the length of the PiM for these subjects.

2. Methods

2.1. Subject selection

The institutional review board of the University of Tennessee at Chattanooga approved this project. Subjects were eligible for inclusion in the study if the following criteria were satisfied: height ≤ 165 cm, mass ≤ 68 kg, no participation in a study involving ionizing radiation within the past year, no current or planned pregnancy within 6 months after completion of the study, non-smoker, and no known spinal or hip pathology. On the day of CT scanning, the subjects did not exercise before testing. The subjects underwent three CT scans of the pelvic region: one in a resting (supine) position and two in stretch positions. The height limitation was placed on the subjects to ensure that the subjects could stretch while in the CT gantry. All subjects signed an informed consent.

2.2. Computed tomography

Three spiral CT scans of the pelvis and proximal portion of the femur were obtained for all subjects (General Electric LightSpeed VCT scanner, Little Chalfont, UK). The subjects were in a resting (supine) position for the first scan. Two CT scans of the pelvis and proximal portion of the femur were then performed in random order with one randomly selected (i.e., left or right) hip joint stretched. To ensure maximal elongation [11,12], the subjects stretched their piriformis muscle before the second and third CT scans using stretches lasting 20–30 s repeated over a 5-min period, for a total of 7–14 stretches. Stretching was achieved by actively moving the hip joint followed by passive overpressure to achieve the maximal tolerable stretch position without pain. One stretch consisted of 90° hip flexion, followed by maximal horizontal adduction, followed by maximal external rotation (ADD stretch, Fig. 1). The other stretch consisted of 90° hip flexion, followed by maximal external rotation, followed by maximal horizontal adduction (ExR stretch) [10,13]. A physical therapist (DL) supervised the stretch positions and collected goniometric measurements of the hip joint for the two stretch positions immediately before the CT.

2.3. Data reduction

The DICOM CT data for all subjects were retro-reconstructed and exported into modeling software (Mimics, Materialise, Plymouth, MI). Masks of the sacrum, pelvis, and femur were created on the stretched side and manually edited to exclude CT scatter and musculoskeletal soft tissues. Hollow spaces (e.g., medullary cavities) were filled, as they might have skewed subsequent alignment operations. Three-dimensional renderings of the sacrum, pelvis, and femur were created and evaluated for completeness, contrast between bone and soft tissue, and quality (i.e., low scatter, low beam hardening). The renderings of the femur from the supine position were copied and aligned onto the femora in the stretched positions using the *Best Fit Alignment* tool in a reverse engineering software program (Studio 12, Geomagic, Research Triangle Park, NC). This ensured that for each subject the renderings of the femora had identical length and surface topography in all three positions. All 21 renderings (i.e., 1 supine rendering and 2 stretched renderings for each of 7 subjects) were considered of acceptable quality and were used in the analyses.

2.4. Coordinate system for femoral position

A global three-dimensional Cartesian coordinate system was defined for each set of models to accurately describe changes in hip joint position (Fig. 2). The plane that best bisected each pelvis was identified using the *Plane of Best Symmetry* tool (Studio 12) and was defined as the *YZ* (mid-sagittal) plane. The *XY* plane was set to be parallel to a line running from the sacral promontory on midline to the posterior end of the pubic symphysis. These anatomic landmarks were used because they were consistent for all CT scans within each subject. The positive *X* axis was set to point to the subject's left and the positive *Y* axis was set to point in a superoposterior direction. These constraints were necessary to consistently define the rotational orientation of each set of bone models in three-dimensional space. It was not necessary to define the exact location of the origin relative to the models, as this would have no impact on their rotational orientation.