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Original research

Effect of pelvic, hip, and knee position on ankle joint range of motion

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Abstract

Objective: To determine if pelvic posture, hip, and knee positions influence range of motion about the ankle joint.
Study design: Quasi-experimental repeated measures.
Setting: Biomechanics laboratory in a university setting.
Participants: Eleven men and six women free of ankle joint trauma.
Main outcome measures: Range of motion about the ankle joint.
Results: ANOVA revealed a significant difference for position main effect on ankle joint range of motion ($p = 0.01$). Post-hoc tests revealed that ankle joint range of motion significantly decreased as participants moved from flexion (i.e., 90° hip and 90° knee), to supine, and to long sitting (47.3°, 38.8°, and 16.4°; $p < 0.05$). No significant differences were revealed for pelvic posture ($p = 0.64$).
Conclusions: These findings indicate that pelvic posture may not influence ankle joint range of motion regardless of hip and knee joint positions. However, the combination of hip flexion and knee extension (i.e., long sitting) produces the greatest deficits in ankle joint range of motion.

Keywords: Biomechanics; Neural tension; Fascia; Muscle; Flexibility

1. Introduction

Fascia is a type of fibrous connective tissue found throughout the body and its primary purpose is to support the spine and transfer loads between the spine, pelvis, legs, and arms (Vleeming, Pool-Goudzaard, Stoeckart, Van Wingerden, & Snijders, 1995). According to Barker and Briggs (1999), fascia in the thoracolumbar region facilitates load transfers between the legs and trunk. In the lower extremity, the long head of the biceps femoris is continuous with the sacrotuberous ligament which is continuous with thoracolumbar fascia (Vleeming et al., 1995). Vleeming et al. found that lateral traction to the biceps femoris tendon displaced the interspinous ligament between L5 and S1. The results of Vleeming et al. support the idea that fascia connections have a load transferring effect even between joints that are far removed from each other.

Gerlach and Lierse (1990) performed a cadaver dissection which identified a different continuous fascia region between the pelvis and feet. This region specifically includes the fascia latae of the iliotibial tract, femoral intermuscular septa, crural fascia, and crural intermuscular septa. The aforementioned fascia may have a load transferring effect from the pelvis to the feet similar to the load transferring effect observed by Vleeming et al. (1995).

In addition to fascia, passive neural tissue may also affect load transfers from the pelvis to the feet.

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For example, a cadaveric study by Coppieters, Alshami, Barbri, Souvlis, Kippers, and Hodges (2006) observed greater sciatic and tibial nerve tension in the presence of hip flexion and ankle joint dorsiflexion. Clinical observations have documented similar results; knee joint range of motion (ROM) decreased with hip flexion and ankle joint dorsiflexion (Boland & Adams, 2000; Gajdosik, LeVeau, & Bohannon, 1985; Johnson & Chiarello, 1997). Collectively, the anatomical and clinical studies in this area indicate that passive tissues may form a complete system from the pelvis to the feet.

Accordingly, an anterior pelvic tilt may influence ankle joint biomechanics (e.g., ROM) due to passive fascia and neural connections. Because no single muscle crosses the ankle, knee, and hip joints, the idea that pelvic or trunk posture influences ankle joint biomechanics is not intuitive unless non-muscular structures are capable of exerting or controlling forces that alter distal joint mechanics. The extent to which pelvic posture influences ankle joint ROM is not well documented and may provide a better theoretical understanding of how passive tissues such as fascia and nerves, not just muscle, influence human motion.

Accordingly, the purpose of this study was to examine how pelvic tilt in the sagittal plane influences ROM about the ankle joint. Since the position of the hip and knee may influence load transfers between the trunk and the foot (Gerlach & Lierse, 1990), a secondary purpose was to assess how position of these joints interact with pelvic posture. It was hypothesized that an anterior pelvic tilt would influence ankle joint ROM when the knees are extended and the hips are flexed. From a practical perspective, a better appreciation for the role of passive tissues in human movement may lead to alternative treatment techniques for ankle or low back pathologies that focus on fascia imbalances and not just muscle imbalances (Dettori, Bullock, & Franklin, 1995; Elnaggar, Nordin, Sheikhzadeh, Parnianpour, & Kahanovitz, 1991).

2. Methods

2.1. Participants

Seventeen volunteers from a university student population were asked to participate in the investigation. The sample included a mixed gender (i.e., 11 males and six females) as pilot data indicated males and females would respond similarly to the stretching protocol. Participants were free from ankle surgery, ankle trauma, inversion/eversion ligament rupture and bone fracture, and physically active (30 min of dynamic exercise) 3–4 days per week, in the last year. Participant physical characteristics were (mean ± SD): men; height 179 ± 7.96 cm, mass 79.3 ± 11.6 kg, and age 24.4 ± 1.21 yrs; women; height 171 ± 5.37 cm, mass 64.4 ± 10.4 kg, age 22.3 ± 1.47 yrs. Each participant was required to read and sign an informed consent document approved by the University Institutional Review Board.

2.2. Equipment

A Biodex isokinetic dynamometer (Biodex Medical Systems, Inc., Shirley, NY, USA) was used to quantify the dependent variable of interest: passive ankle joint ROM. Test–retest reliability of the Biodex for measuring change in ankle joint angle revealed high intratester reliability (ICC = 0.88, 0.97; $F_{1,9} = 6.23$). Feiring, Ellenbecker, and Dercheid (1990) and Porter, Vandervoort, and Kramer (1996) have also reported high reliability validity using the Biodex to quantify torque and ankle joint angle.

A 60 Hz Canon ES290 8 mm camcorder (Ohta-Ku, Tokyo, Japan) was used to image pelvic angle in the sagittal plane 2.3 m from the Biodex recumbent chair. Prior to data collection on each participant, a 0.139 m scaling rod was recorded at the same distance from the camera as the Biodex chair to aid in converting pixels to meters. The video images were digitized using Peak Motus Motion Analysis System (Englewood, CO, USA) and the smoothed coordinate data were used for computing pelvic tilt angles according to Fig. 1.

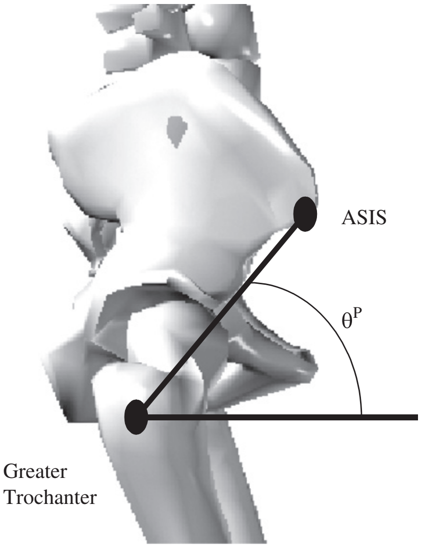

Fig. 1. Schematic diagram of the convention used to specify pelvic (*P*) angle (*θ*). Pelvic angle was determined from coordinate data taken from digitization of video images that contained the anterior superior iliac spine (ASIS) and greater trochanter.

2.3. Procedures

Each participant was required to attend a 1-h test session. Upon arrival to the biomechanics laboratory, the participants were instructed in the testing protocol which included how to stop the Biodex, with a kill switch, when they perceived mild discomfort in the ankle plantar flexor calf muscles. Mild discomfort is a technique used by previous researchers to determine a flexibility end point (Bandy & Irion, 1994; Bandy, Irion, & Briggler, 1997; Sullivan, Dejulia, & Worrell, 1992) and was discussed with subjects as a moderate stretching sensation similar to that felt during a stretch prior to undertaking exercise.

The independent variables were two pelvic postures (neutral and anterior pelvic tilt) accompanied by three leg positions. Position 1 (flexion), while lying supine, required bilateral 90° hip and 90° knee flexion (Fig. 2). Position 2 (supine) was assumed by lying supine on a Biodex table in anatomical position (Fig. 3).

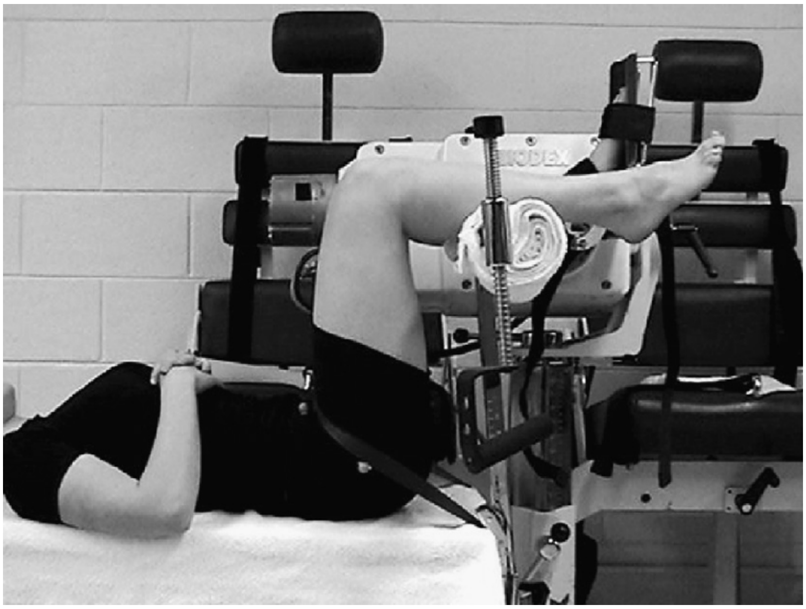

Fig. 2. Flexion position with a neutral pelvic posture.

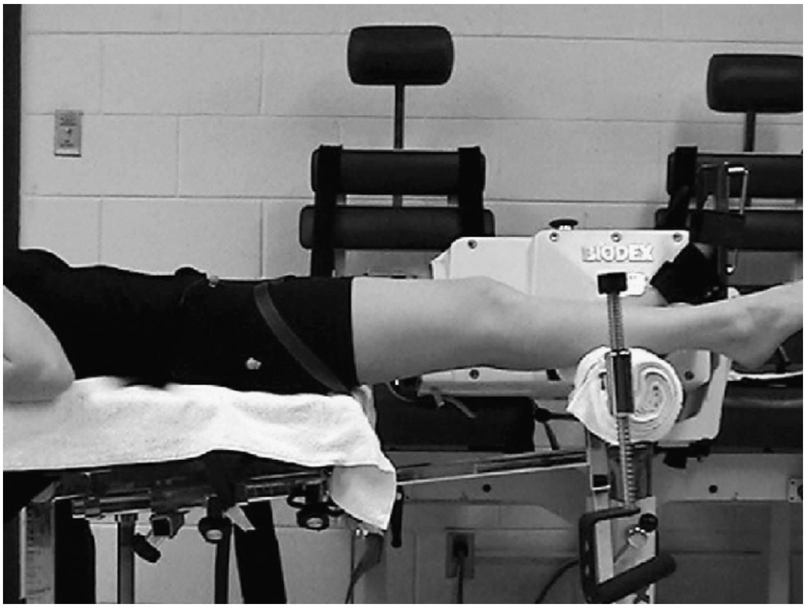

Fig. 3. Supine position with a neutral pelvic posture.

Position 3 (upright or long sitting), was performed with 90° of hip flexion and the knees fully extended (Fig. 4). Anterior pelvic tilt was induced for each position with a half circular shaped foam (closed-cell) wedge (radius $= 5.08$ cm) placed between the lumbar spine and surface of the recumbent chair (Fig. 5). A manual goniometer was used to ensure proper hip and knee joint angles for each treatment before testing. Position and pelvic posture were randomly assigned.

Once the participant was in the proper position and pelvic tilt, their left foot was securely attached to the Biodex ankle plate with two straps; the participant was given the kill switch and blindfolded to ensure no visual perception. The Biodex was then manually activated by the researcher and the left foot plate moved passively into dorsiflexion at 5°/s from 10° plantar flexion. The foot was moved into dorsiflexion until the participant perceived mild discomfort and then they stopped the movement. The rate of 5°/s is in harmony with previous

Fig. 4. Upright long sitting position with the neutral pelvic posture.

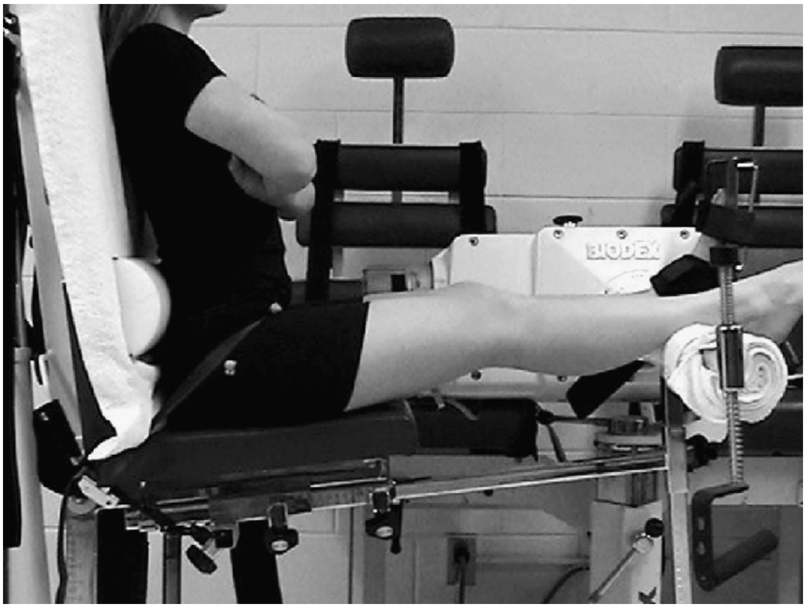

Fig. 5. Upright sitting position illustrating the foam wedge used to impose an anterior pelvic posture.

research indicating that minimal muscle activity occurs at a rate less than 20°/s (Bressel & McNair, 2001; Magnusson, Simonson, Dyhre-Poulsen, Aagaard, Mohr, & Kjaer, 1996; Muir, Chesworth, & Vandervoort, 1999). To rule-out any active muscle involvement, electromyographic (EMG) activity was monitored using methods described previously (Bressel & McNair, 2001). It was observed that EMG activity of muscles gastrocnemius and tibialis anterior were less than 1% of maximal voluntary contraction for all tests. Immediately after each measurement the Biodex was disengaged and the participant was removed from the Biodex and given a 5-min relaxation period (Muir et al., 1999). This process was repeated for each position and pelvic posture.

2.4. *Data analysis*

The change in ankle angle with respect to 10° of plantar flexion served as the dependent variable. A two-way within-participant analysis of variance's (ANOVA's) was used to determine the effect of pelvic posture (factor 1: neutral and anterior pelvic tilt) and joint position (factor 2: supine, flexion, and long sitting) on the dependent variable. Follow-up multiple comparisons (Bonferroni) were also employed for the position factor. Alpha was set at 0.05 for all comparisons and effect size was reported (partial eta squared/Cohen's *d*). With a sample size of 17 participants, a two-way ANOVA with $\alpha = 0.05$ significance level, has 80% power to detect a difference among the pelvic posture mean variances of 0.02, 99% power to detect a difference among the position mean variances of 0.08, and 99% power to detect an interaction among the factor mean variances of 0.13, assuming that the common standard deviation is 0.50. To help clinicians better interpret any significant or non-significant results, the magnitude of changes in ankle joint ROM between conditions and their 95% confidence intervals (CI) were calculated.

3. Results

Prior to computing the ANOVAs, a paired-samples *t*-test, from motion analysis data, indicated a significant degree difference for change in pelvic tilt, (neutral = 33.5±4.43° vs anterior pelvic tilt = 25.4±4.11°; $p = 0.001$, $d = 0.89$). ANOVAs indicated the pelvic posture main effect was not significant for the dependent variable: $F(1,15) = 4.13$, $p = 0.06$, $\eta^2_p = 0.22$. Position main effects were significant for the dependent variable ($F(2,30) = 174$, $p = 0.01$, $\eta^2_p = 0.92$) and the posture–X position interaction, in spite of the significant change in pelvic angle, was not significant ($F(2,30) = 1.96$, $p = 0.16$, $\eta^2_p = 0.12$).

Table 1
Passive ankle joint range of motion (ROM) values (mean±SD) for three lower limb positions and pelvic postures

Position	Pelvic posture		ΔROM (95% CI)
	Neutral	Anterior tilt	
Supine	39.8 (6.86)	37.8 (8.74)	2.00 (−0.31–4.78)
Flexion	47.1 (7.96)	47.4 (9.17)	0.38 (−3.7–2.96)
Sitting	18.1 (8.10)	14.8 (6.47)	3.31 (0.40–5.37)

The magnitude of changes (Δ) in ROM between pelvic postures and their 95% confidence intervals (CI) are also reported.

Table 2
Lower limb position values (mean±SEM) and the magnitude of changes (Δ) in ankle joint ROM between positions and their 95% confidence intervals (CI)

Positions	ΔROM (95% CI)
Flexion (47.3±2.0)—supine (38.7±1.9)[a]	8.47 (4.73–12.2)
Supine (38.7±1.9)—sitting (16.4±1.7)[a]	22.3 (18.0–26.7)
Flexion (47.3±2.0)—sitting (16.4±1.7)[a]	30.8 (25.3–36.3)

[a] Significantly different between conditions ($p < 0.05$).

Post-hoc comparisons revealed that mean ankle joint ROM values for the flexion condition were 22% greater than supine values, $t(15) = -6.11$, $p < 0.01$, $d = 1.58$, and 187% greater than long sitting values, $t(15) = 15.1$, $p < 0.01$, $d = 3.89$. The supine values were also greater (135%) than long sitting values $t(16) = 14.7$, $p < 0.01$, $d = 3.67$. Table 1 presents the ROM values, spread of data, and change scores (95% CI) for pelvic posture and Table 2 presents these same measures for the lower limb position factor.

4. Discussion

The results of this study revealed a significant effect for the position factor and no effect for pelvic posture. Although the results do not support the hypothesis that a change in pelvic tilt influences ankle joint ROM, it is important to note the hip and knee joints position influence on the dependent variables, specifically in long sitting.

4.1. *Effect of hip and knee position*

In this study, ankle ROM steadily decreased as participants moved from flexion (i.e., 90° hip and 90° knee), to supine, to long sitting (47.3°, 38.8°, and 16.4°). The magnitude of these changes was substantial as reported in Table 2. Indirect comparisons with previous research support our results. Gajdosik et al. (1985) observed a decrease in hip ROM during the straight leg raising test when the foot was moved from a plantar flexed position (≈35.9°) to a dorsiflexed position (≈4.3°), and Johnson and Chiarello (1997) reported a 60% decrease in knee extension ROM when the ankle was moved from a neutral to dorsiflexed position during the slump test.

Anatomical studies would indicate that joint position changes at the hip and knee influence ankle ROM by altering tension within passive tissues that span from the lumbar spine to the foot (Gerlach & Lierse, 1990). For example, in the long sitting position, ankle joint ROM deficits were the greatest and may be the result of pulling tension transferring distally from the thoracolumbar fascia, fascia latae, broad fascia, popliteal fascia, and sciatic nerve, while the dorsiflexed foot produced an opposite pulling tension that transferred proximally through the crural, popliteal, broad fascia, and tibial nerves of the leg completing the connective tissue system from the lumbar spine to the foot (Coppieters et al., 2006; Vleeming et al., 1995).

In the flexed position (i.e., 90° hip and 90° knee), passive tissues (i.e., fascia and nerves) may have developed tension due to 90° of hip flexion, yet, tension may have been quickly lost when the knee was flexed. In the supine position, ankle joint ROM decreased by 8.47° in comparison to the flexed position suggesting that distal joint changes (i.e., knee) will have a greater effect on ankle joint ROM than will joint changes at more proximal joints (i.e., hip; see Table 2).

This finding may be taken into consideration by clinicians who want to increase ankle joint ROM for their patients. Initially, joint mobilizations may be performed with the knees and hips flexed to allow greater laxity and focus on local tissues and then progress to the long sitting position where mobilizations may encompass more global tissues that transfer loads. This systematic approach for performing mobilizations may be more effective at increasing ankle joint ROM since each position may target different tissues, but future research is needed to support this contention.

4.2. *Effect of pelvic posture*

Pelvic posture main effect was not significant; however, partial eta squared ($\eta^2_p = 0.22$) revealed a large effect as ROM approached significance ($p = 0.06$) with low observed power (0.48). Since power is typically low for non-significant results, the change scores and their 95% CI are reported in Table 1. These measures will help the readers decide the impact of pelvic posture on ankle joint ROM and the precision of the statistical estimates. The non-significant result was unexpected as preliminary work revealed significance for pelvic posture (Mitchell & Bressel, 2005). One difference between the studies was that the current study required a strict 90° hip flexion position whereas the latter was not monitored. Consequently, some participants in the current study found the long sitting position difficult to achieve and the stretching sensation within the hamstrings may have distorted their perception of mild discomfort in the ankle joint. Future research in this area may wish to use hamstring length as a covariate and assess how different hip joint angles (e.g., 45° vs 90°) interact with pelvic posture.

From a practical perspective, it is important to recognize that the lower limb is a kinetic chain and that while pelvic posture may not directly influence passive ankle joint ROM when the knees and hips are in a fixed position, as observed in this study, pelvic posture does seem to influence knee joint ROM (Sullivan et al., 1992). As such, a change in knee joint ROM may influence ankle joint ROM via biarticular muscles that cross the knee and ankle joints (i.e., gastrocnemius). This kinetic link is important in the diagnosis of abnormal gait patterns because a change in pelvic posture may influence ankle joint ROM and vice versa.

4.3. *Limitations*

Limitations existed within the present study and should be considered to gain an appreciation for the results of this study. Ankle joint end ROM was determined by the participants' perception of mild discomfort in the calf muscle tendon unit. Although other researchers have used this technique (Bandy & Irion, 1994; Bandy et al., 1997; Sullivan et al., 1992), it may be difficult to perceive equally each time a measurement is taken. In part, the randomized nature of this current study helped to counterbalance any perception changes that may have occurred with repeated stretches. Another perception issue of importance is that participants may have used sensations of mild discomfort at other locations (e.g., posterior thigh) to determine end ROM; although no participants reported doing so in this study. Some researchers (Butler, 1991) would indicate that perceptions of mild discomfort will more likely occur at the joint being stretched (e.g., ankle) and not at proximal joints (e.g., hip and knee) with fixed positions, as was done in the current study. However, further research is warranted to assess the reliability of using one sensory location to determine end ROM about the ankle joint.

Finally, the specific fascia and neural tissues and their individual contribution could not be assessed in this study. That is, both tissue types may have a load transferring effect, but in this study, which passive tissue contributed the most is unknown.

5. Conclusions

Within the limitations of this study the following conclusions may be made:

1. Regardless of hip and knee joint positions, pelvic posture may not influence ankle joint ROM.
2. The long sitting position was most influential in decreasing ankle joint ROM.
3. The supine position was more influential than hip/knee flexion in decreasing ankle joint ROM.

Ethical Approval

Utah State University IRB provided ethical approval for this study.

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Conflict of Interest Statement

There are no conflicts of interest with this study.

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