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Original Article

Ankle motion in common yoga poses

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ABSTRACT

Background: Motion of the ankle is essential for many yoga poses. An understanding of range of ankle motion during typical yoga poses may help the clinician to understand expected outcomes of patients when returning from ankle surgery or injury to yoga.
Methods: The biomechanics of twenty healthy active yogis were collected during seven yoga poses that are common within their practices. Motion capture and force plates were used to assess the range of motion and joint moments of the ankle for each pose.
Results: All poses resulted in plantarflexion and external rotation moments at the ankle joints. Joint loading was highest in single leg poses. The arc of motion used by the study participants in the poses was 29° of sagittal motion, 20° of frontal motion and 35° of transverse motion.
Discussion: Ankle motion was evaluated when healthy yogis perform standard poses. These results may help in discussion with patients regarding expected outcomes after ankle injury or surgery.

1. Introduction

The practice of yoga is becoming increasingly prevalent in the United States and throughout the world and is used for both general well-being and therapeutic purposes [1]. Yoga combines physical practice through poses (asanas) and mental practice through breathing (pranayama) and is considered a mind-body therapy [2]. Yoga is considered a safe form of exercise, and the asanas involve motion of both the upper and lower extremities to increase strength, flexibility, endurance and balance [3]. While the asanas can be modified to allow participation by almost anyone, more advanced practitioners may expect a certain level of flexibility to allow them to perform particular poses.

Though research continues to support yoga practice for a range of populations [3,5], analyses of joint mechanics during the practice of yoga is sparse. Previous research has reported on the biomechanical demands of yoga in older adults who were inexperienced in yoga practice [3,4], and hip joint motions in young and experienced yogis [5] during typical yoga poses. In order to ensure efficacy and safety when prescribing asanas to patients, it is important that the practitioner have a clear understanding of the biomechanical demands of the different poses. Several asanas require considerable involvement of the ankle joint across all planes of motion, but to date, the only report on the biomechanical demands of yoga on the ankle was done on older adults with no previous yoga experience [3]. No previous research has mapped out the biomechanical demands on the ankle joint in young and experienced yogis.

Surgical procedures have been shown to reduce the available motion in the ankle joint [6,7] and yoga is often prescribed as a component in rehabilitation after surgery because it improves flexibility [8,9]. However, as the current literature on the biomechanical demands on the ankle joint during yoga practice in people below 70 years of age is limited, practitioners have no guidelines when prescribing asanas during rehabilitation. It is unknown to what extent patients may be able to participate in yoga after injuries or surgeries that affect ankle motion.

Understanding of the ranges of motion in the ankle may help physicians guide patients who are returning from injury or surgery to have appropriate expectations for their outcomes in terms of participation in yoga. The purpose of this study was to evaluate the motion and loading of the ankle of healthy yogis during common yoga poses.

2. Methods

2.1. Participants

For this study, twenty healthy individuals who routinely practice yoga volunteered for participation. All participants (34.8 ± 10.3 yrs.,

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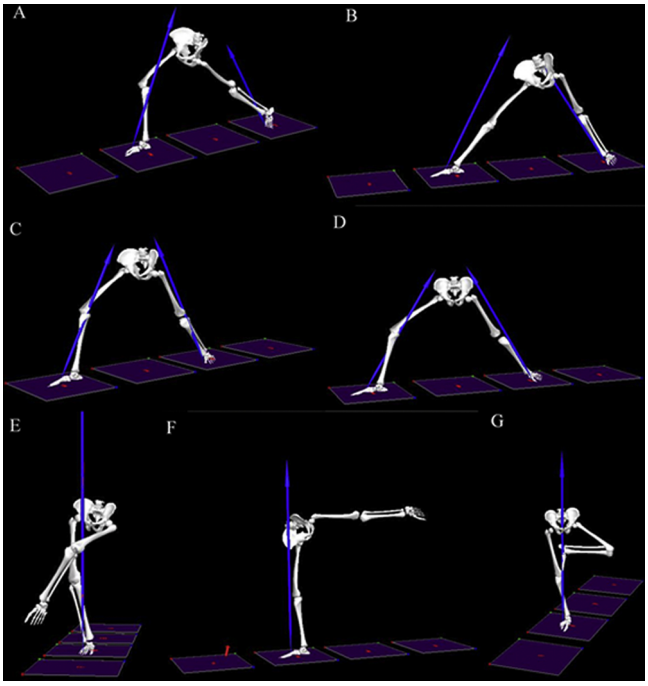

Fig. 1. The yogaasanas in the study are displayed in Visual 3D.

1.63 ± 0.05 m, 62.0 ± 7.7 kg, 3 males and 17 females) had practiced yoga for an average of five years (range one to ten plus) and practiced on average four times per week (range one to seven) at the time of testing and were therefore skilled in the asanas included in this study. All of the participants were healthy at the time of data collection with no previous orthopaedic injuries. Prior to testing, written informed consent was obtained from each participant in agreement with the Institutional Review Board approval.

2.2. Procedure

Following a self-selected, five-minute warm up, the participants were equipped with sixteen low-mass retroreflective markers on specific anatomical landmarks in accordance with the lower body Plug-In Gait model (Vicon, 2002 [18]). All kinematic data were collected using a ten-camera motion capture system (Vicon, Oxford Metrics, Oxford, UK) operating at 100 Hz, and kinetic data was recorded using force platforms (AMTI, Watertown, MA, USA) operating at 1000 Hz.

The participants performed seven common asanas: crescent lunge, triangle, warrior 1, warrior 2(all double leg poses), eagle, half-moon and tree (all single-leg poses)(Fig. 1) [5]. Each asana was performed in a manner which the participant would practice regularly and was not performed as deeply as possible. Each participant performed every pose three times from a neutral standing position and held the pose for fifteen seconds each time. All poses were performed on both the left and right leg, however previous studies found no between-leg differences in this sample [5], so the analysis was only performed on poses with the right leg forward, or while standing on the right leg.

2.3. Data analysis

The kinetic and kinematic data was imported into Visual3D (C-motion, Germantown, MD, USA), and was filtered using a 2 Hz and 6 Hz low-pass Butterworth filter respectively based on a residual analysis.

The three-dimensional ankle displacement and joint moments during each pose were extracted and imported to Microsoft Excel (Microsoft Corp., Redmond, WA, USA) for analysis. The average joint displacements and joint moments were calculated for the middle five seconds of the hold of the pose. Means and standard errors (SE) for the displacements in the three planes of motion were graphed.

3. Results

Ankle motion in each pose is highlighted for the three different planes of motion (sagittal, frontal, and transverse) in Figs. 2–4. The arc of motion used by the study participants to achieve all the asanas was 29° sagittal motion, 20° frontal motion and 35° of transverse motion. angles of both ankles were observed during warrior 1 (front foot: 13.8° ± 3.3, back foot: 13.4° ± 0.5), while the largest plantarflexion angles were seen during triangle for both ankles (front foot 15.8° ± 1.2,

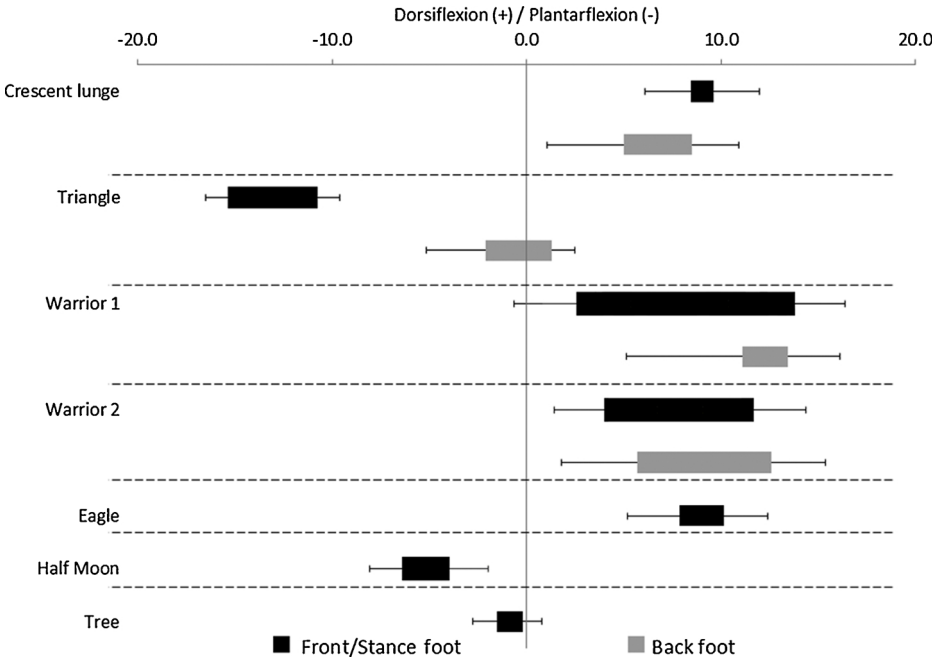

Fig. 2. Ankle dorsiflexion and plantar flexion during yoga poses.

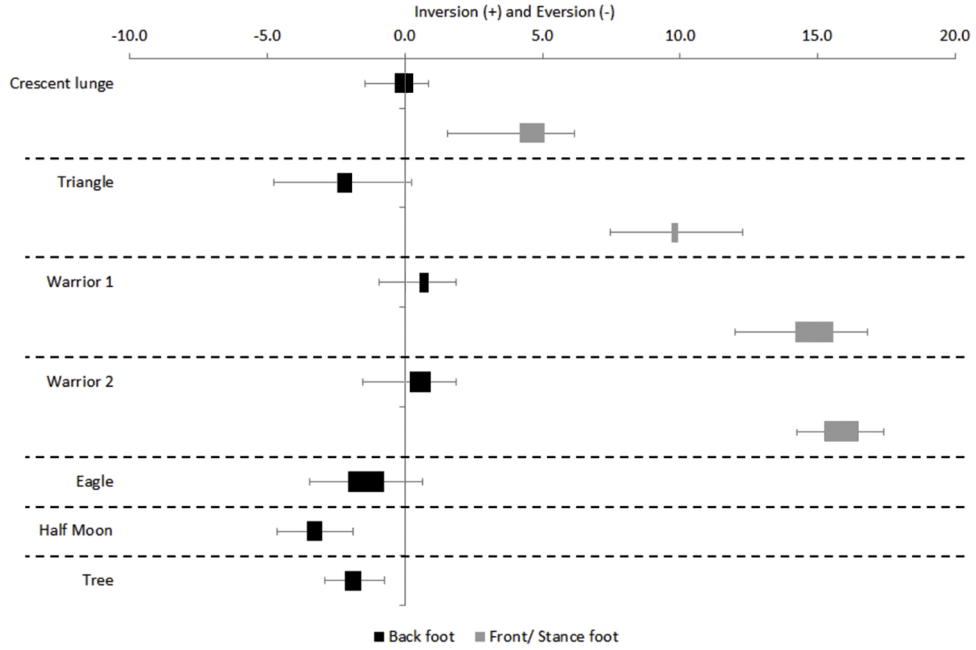

Fig. 3. Ankle inversion and eversion motion during yoga poses.

back foot 2.1° ± 2.7). Table 1 shows the range of motion for each foot in each asana.

The analysis of the peak joint moments also revealed the different torques acting on the ankles during the asanas (Table 2). The results showed that all asanas elicited plantarflexion moments and external rotation moments on both ankles. The direction of the frontal plane moment varied between the asanas. The analysis showed that the single-legged poses elicited larger moments. The half-moon pose produced the greatest plantarflexion moment (1.03 ± 0.28 Nm kg^{-1}), the eagle pose had the highest frontal plane moment (0.25 ± 0.27 Nm kg^{-1}), and the warrior 2 pose had the highest moment in the transverse plane (0.12 ± 0.08 Nm kg^{-1}).

4. Discussion

In this study, the ankle motion and loading in adults who had practiced yoga regularly for an average of five years was examined. The results outline the demands of seven common asanas on the ankle joint, which can provide guidelines for medical practitioners and therapists working with patients returning from ankle pathology or injury. This is, to the best of the authors' knowledge, the first time that the biomechanical demands on the ankle joint during yoga has been examined

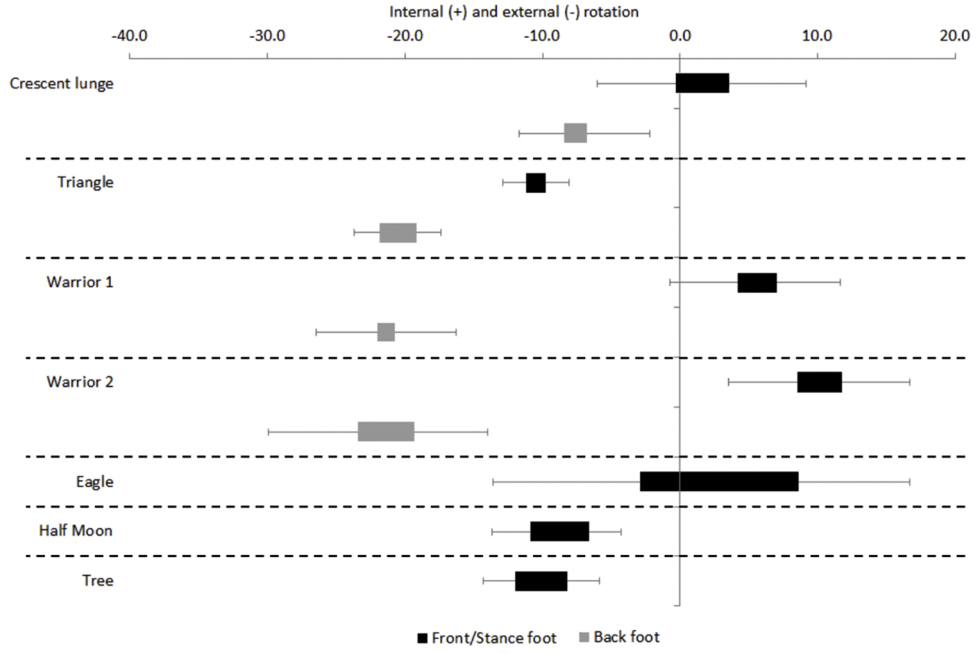

Fig. 4. Ankle internal and external rotation during yoga poses.

Table 1
Peak joint angle for each pose.

		Dorsiflexion (+)/Plantarflexion (−)	Inversion (+)/Eversion (−)	Internal (+)/External (−) rotation
Crescent Lunge	Front foot	+9.6 (2.4)	−0.4 (1.1)	+3.5 (5.9)
	Back foot	+8.5 (2.4)	+5.1 (1.1)	−8.7 (6.1)
Triangle	Front foot	−15.8 (1.2)	−2.5 (2.3)	−11.2 (1.7)
	Back foot	−2.1 (1.2)	+9.9 (2.2)	−21.8 (1.8)
Warrior 1	Front foot	+13.8 (3.3)	+1.1 (0.9)	+7.0 (4.9)
	Back foot	+13.4 (0.5)	+15.6 (2.2)	−22.7 (4.4)
Warrior 2	Front foot	+11.7 (2.6)	+0.9 (0.9)	+11.8 (5.3)
	Back foot	+12.6 (2.8)	+16.5 (0.9)	−23.5 (5.3)
Half Moon		−6.4 (1.7)	−3.6 (1.1)	−10.8 (2.3)
Eagle		+10.2 (2.3)	−2.0 (1.4)	+8.6 (10.8)
Tree		−1.5(1.3)	−2.2 (0.8)	−12.0 (2.3)

Table 2
Joint moments Nm kg^{-1} for the ankle joints during the different poses.

		Dorsiflexion (+)/Plantarflexion (−)	Inversion (+)/Eversion (−)	Internal (+)/External (−) rotation
Crescent Lunge	Front foot	−0.54 (0.16)	0.10 (0.22)	−0.11 (0.10)
	Back foot	−0.53 (0.18)	−0.21 (0.07)	−0.10 (0.01)
Triangle	Front foot	−0.24 (0.10)	−0.13 (0.12)	−0.10 (0.11)
	Back foot	−0.41 (0.10)	−0.19 (0.11)	−0.03 (0.01)
Warrior 1	Front foot	−0.51 (0.12)	0.11 (0.08)	−0.12 (0.08)
	Back foot	−0.58 (0.12)	−0.23 (0.15)	−0.05 (0.07)
Warrior 2	Front foot	−0.40 (0.12)	0.11 (0.13)	−0.02 (0.05)
	Back foot	−0.39 (0.14)	−0.29 (0.12)	0.06 (0.06)
Half Moon		−1.03 (0.28)	−0.11 (0.15)	−0.03 (0.05)
Eagle		−0.79 (0.35)	0.25 (0.27)	−0.03 (0.07)
Tree		−0.86 (0.17)	−0.13 (0.11)	−0.12 (0.04)

on healthy and experienced yogis. Previous studies have reported on yoga's demands on the hip joint [5], and the biomechanics of common asanas when performed by older adults [3].

This study included seven poses that are commonly included in yoga practice [5] and that were considered to challenge the ankle joint. The study by Salem et al. [3] presented biomechanical profiles of 19 poses specifically selected to suit an older population. The population in this study were younger and experienced yogis so the analyzed asanas were different and in many cases, more advanced than those presented previously [3]. However, three of the asanas were included both studies and therefore provide an insight into differences between the populations. During the tree pose, the younger population trended toward a slight plantarflexion angle on the stance foot (1.5°) while the older population was reported to utilize a dorsiflexed ankle (9.2°), however both populations presented a plantarflexion moment. During the warrior 2 pose, both populations utilized a similar angle in the front foot (younger – 13.8° dorsiflexion, and older – 10.2° dorsiflexion). However, the back foot dorsiflexion angle was considerably larger in the older population (21.1°) compared to our younger cohort (12.6°). The younger population also experienced larger joint moments about both ankles than their older counterparts suggesting perhaps different load distribution strategies by the two populations. The crescent lunge asana also differed between the populations, where our participants achieved 9.6° and 8.5° dorsiflexion in the front and back ankles respectively while the older practitioners achieved 6.3° and 18.8° respectively. Similar to warrior 2, the joint moments in the ankles during the crescent lunge were larger for our participants that those reported in the older population.

The kinematic comparison between the young and experienced population in this study with the older and novice cohort in the study by Salem et al. [3] provided a unique insight into the physical effects of experience and age on yoga performance. It is generally accepted that flexibility and strength decrease with age [10], and flexibility-type training, such as dance, has been shown to increase ankle range of motion [11]. It is therefore surprising that range of motion of the ankle was similar in the older novice participants compared to our younger experienced population. It is possible that differences in data collection protocols may have affected these comparisons. Regardless, the similar joint mobility of the ankles between the two populations are encouraging for using yoga to maintain joint flexibility in older adults. Although it is likely that prolonged yoga practice would also result in increased ankle flexibility and perhaps slow the age-related declines in joint range of motion, it has not yet been established.

It has been shown that yoga can increase trunk flexibility in individuals with chronic lower back pain [8,9] and it is likely that it may also benefit ankle flexibility. In addition to aging, orthopaedic injury or surgery can also negatively affect the range of motion of the ankle joint. High rates of postoperative stiffness has been reported following ankle fractures and fracture dislocations [6,7], which could affect the ability to perform certain yoga poses. In particular, older patients who have been treated for ankle fractures have considerably reduced ankle function after surgery, with one study reporting that only 56% were able to return to their pre-injury activity level one year after surgery [12]. Returning to physical activity after injury and surgery is important, especially for older individuals where it can be essential for survival [13]. Yoga is one activity that is often recommended early in rehabilitation [2,9]. The present study showed that the ankle motion required for several common asanas might be beyond what patients with severe ankle injuries may be able to perform early in the rehabilitation process.

The present findings showed that the joint loading was highest during single leg poses, which support previous research [3]. However, the same poses had the lowest range of motion demands in both the sagittal and frontal planes, so practitioners should consider the focus of the rehabilitation (flexibility or strength development) when selecting which poses to include in their program.

Poorly managed or complicated ankle injuries may lead to ankle fusion or replacement surgery. Both procedures affect the mobility of the ankle joint with replacement having been reported to allow greater range of motion after recovery [14]. Arc of motion after ankle replacement is approximately 30–40° in the sagittal plane [15,16], and about 22° after ankle arthrodesis [17]. It is unknown if patients are able to participate in yoga after these surgeries or if yoga practice may help maintain ankle range of motion if included in the rehabilitation, and these questions pose interesting directives for future investigations.

One limitation of this study is that the motion capture methodology used only models motion between the shank and foot segments and did not include the multiple joints within the foot. Further, this study used the standardized Vicon Plug-In Gait model [18], which has inherent error in measuring motions about the ankle joint [19].

In conclusion, the present study has quantified the three-dimensional motions and joint moments of the ankle joint during seven common yoga poses when performed by experienced practitioners. Awareness of the joint angles and loading associated with each asana may help medical professionals and therapists when discussing return to yoga after injury or expectations after surgery.

Author declaration

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