

# Gastrocnemius recession: A cadaveric study of surgical safety and effectiveness

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**Background and purpose** — Many methods of gastrocnemius lengthening have been described, with different surgical challenges, outcomes, and risks to the sural nerve. Our aims were (1) to locate the gastrocnemius muscular-tendinous junction in relation to the mid-length of the fibula (from here on designated the mid-fibula), (2) to compare the dorsiflexion achieved with dorsal recession or ventral recession, and (3) to determine the risk of injury to the sural nerve during gastrocnemius recession.

**Methods** — In 10 pairs of fresh-frozen adult cadaveric lower extremities transected above the knee, we measured dorsiflexion, performed dorsal or ventral gastrocnemius recession at the mid-fibula, and then measured the increase in dorsiflexion and fasciotomy gap. We noted the course of the sural nerve and whether the gastrocnemius muscle provided it with enough muscular coverage to protect it during recession.

**Results** — Dorsal and ventral recession produced statistically ( $p < 0.05$ ) and clinically significant mean increases in dorsiflexion with extended knee from 12° to 19°, but they were not statistically significantly different from each other in this measure or in fasciotomy gap size. At the mid-fibula, the sural nerve coursed superficially between both heads of the gastrocnemius muscle in 14 of 20 specimens. Sufficient gastrocnemius muscle coverage to protect the sural nerve was provided by the medial head in 18 of 20 specimens and by the lateral head in only 5 of 20 specimens.

**Interpretation** — A ventral gastrocnemius recession proximal to the mid-fibula level poses less risk to the sural nerve than a recession at the mid-fibula. This procedure provides adequate lengthening (1–3 cm) and increased dorsiflexion (compared with baseline), with less risk to the sural nerve than is incurred with recession at the mid-fibular reference line.

Gastrocnemius-soleus complex lengthening has gained popularity as a treatment for many foot and ankle disorders caused by contracture of the gastrocnemius muscle. The surgical anatomy, methods, and clinical outcomes of gastrocnemius-soleus complex lengthening have been investigated and described by many authors (DiGiovanni et al. 2002, Aronow et al. 2006, Blitz and Eliot 2007, 2008, Firth et al. 2013, Tinney et al. 2014). Several approaches to reducing a gastroc-soleus equinus involve a fasciotomy or tenotomy of the gastrocnemius or triceps surae tendon that is either dorsal or ventral and at either proximal or distal level in the triceps surae or gastrocnemius tendon (Vulpis and Stoffel 1913, Silfverskiöld 1923, Hoke 1931, White 1943, Strayer 1950, Baker 1956, Hansen 2000, Saraph et al. 2000, DiGiovanni et al. 2002, Pinney et al. 2004, Barouk et al. 2006, Blitz and Rush 2007, Herzenberg et al. 2007, Hamilton et al. 2009, Maskill et al. 2010, Abbassian et al. 2012, Chimera et al. 2012).

Variability in the anatomy of the gastrocnemius-soleus complex makes location of the junction of the gastrocnemius and soleus tendon difficult (White 1943, Cummins et al. 1946, van Gils et al. 1996, Tashjian et al. 2003, Pinney et al. 2004, Blitz and Eliot 2007, Elson et al. 2007). Furthermore, the various procedures involve performing the recession at different levels (Herzenberg et al. 2007, Firth et al. 2013), each presenting its own surgical challenges and often placing the sural nerve at risk during the recession (Webb et al. 2000, Mestdagh et al. 2001, Tashjian et al. 2003) (Figure 1).

Our aims were (1) to locate the gastrocnemius muscular-tendinous junction in relation to the mid-fibular reference line (MFRL), (2) to measure and compare the dorsiflexion achieved with dorsal recession or ventral recession, and (3) to determine the risk of injury to the sural nerve.

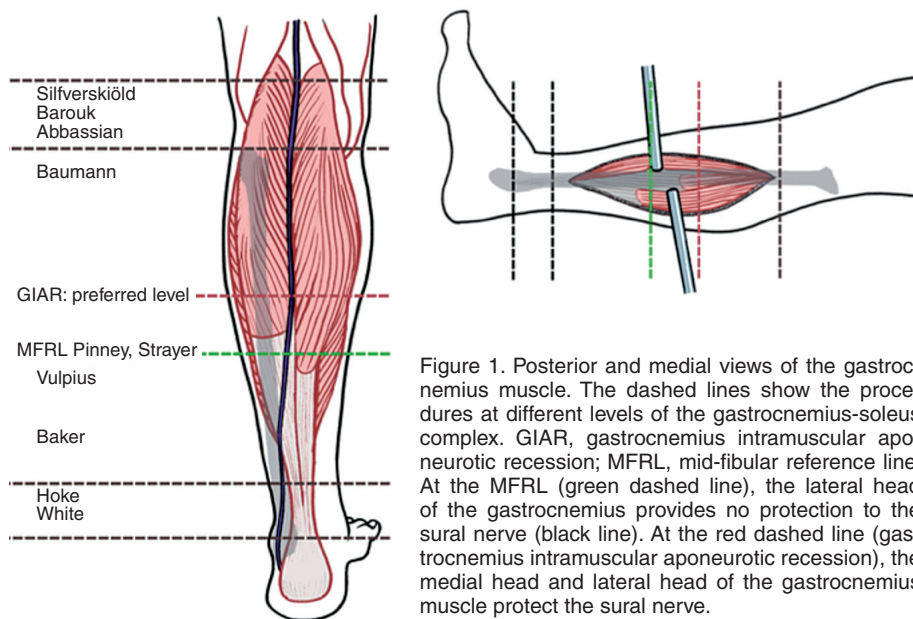


Figure 1. Posterior and medial views of the gastrocnemius muscle. The dashed lines show the procedures at different levels of the gastrocnemius-soleus complex. GIAR, gastrocnemius intramuscular aponeurotic recession; MFRL, mid-fibular reference line. At the MFRL (green dashed line), the lateral head of the gastrocnemius provides no protection to the sural nerve (black line). At the red dashed line (gastrocnemius intramuscular aponeurotic recession), the medial head and lateral head of the gastrocnemius muscle protect the sural nerve.

## Material and methods

We examined 10 paired above-knee-amputated fresh-frozen adult cadaveric legs obtained from our state anatomy board. The mean age was 69 (44–93) years. No specimens showed any gross evidence of abnormality (e.g. arthrodesis, severe arthritis, or bone disease). Specimens were thawed at room temperature (approximately 22°C) before use. The length of the fibula was measured with a ruler from the fibular head to the distal end of the lateral malleolus. The skin was marked at the mid-length of the fibula and was defined as the mid-fibular reference line (MFRL) (Figure 1). The Silfverskiöld test (Silfverskiöld 1923) was performed by measuring ankle dorsiflexion with the knee extended and with it flexed at 90°. The amount of dorsiflexion was measured to within 5° by 2 observers using a goniometer. Skin and subcutaneous tissue at the dorsal aspect of the leg were resected down to the superficial fascia, exposing the whole gastrocnemius-soleus muscular-tendinous unit in continuity. The distances from the distal end of the lateral malleolus to (1) the muscular-tendinous junction of the medial head of the gastrocnemius muscle, (2) the lateral head of the gastrocnemius muscle, (3) the merging of the medial head of the gastrocnemius, and (4) the merging of the lateral head of the gastrocnemius with the soleus were measured and divided by the length of the fibula to give a normalized location. Note that the MFRL is, by definition, located at 50% of the fibular length.

First, a dorsal fasciotomy of the gastrocnemius was performed at the MFRL, taking care not to cut the underlying fascia of the soleus muscle. Then, the plantaris muscle was completely cut and the foot was dorsiflexed to achieve lengthening. If the dorsal fasciotomy resulted in an inadvertent total tenotomy (which occurred when the muscular-tendinous junc-

tion was proximal to the MFRL), the procedure was stopped. If there was no total tenotomy, then an additional, ventral fasciotomy was performed.

In the contralateral leg at the MFRL, a ventral fasciotomy was performed first. If there was no space between soleus and gastrocnemius, as was the case with fused tendons, a fasciotomy was performed approximately 1 cm proximal to the fusion line. If the recession did not result in a total tenotomy, an additional dorsal fasciotomy was performed at the MFRL. For all procedures, we used the same protocol: after the first fasciotomy and in cases with a second fasciotomy, the increase in ankle dorsiflexion with the knee in flexion (90°) and extension was measured to the nearest 5° by 2 observers using a goniometer. The distance between the incised edges of the gastrocnemius fascia (fasciotomy gap) was also measured by 2 observers. During all procedures, the course of the sural nerve was observed and assessed for risk of damage.

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## Statistics

We analyzed the effect of experimental factors (fasciotomy type and resection order) on outcome parameters of interest (dorsiflexion angle and fasciotomy gap size) with the leg in flexion and extension using a general linearized latent mixed model with a random-effects term (Stata version 10) to account for repeated measures on legs from a given cadaver. The data are presented as mean with 95% confidence interval (CI). Significance was set at  $p < 0.05$ .

## Results

At the MFRL level, in 18 of 20 specimens we found a muscular part of the gastrocnemius on the medial side; in 5 of these, the lateral side was also muscular. In 2 of the 20 specimens, there was only tendon at the level of the MFRL. The median normalized location of the muscular-tendinous junction of the medial head of the gastrocnemius was at 44% (33–52), and that of the lateral head of the gastrocnemius was at 53% (39–62) (Figure 2).

At the MFRL, we found fusion of the gastrocnemius tendon and dorsal soleus fascia proximal to the muscular-tendinous junction in 7 specimens. In 7 specimens, there was a completely separate gastrocnemius tendon. 3 specimens had a separate (> 1 cm) gastrocnemius tendon at the medial side and direct fusion laterally. 3 specimens had a separate (non-fused) tendon on the lateral side and direct fusion with the soleus

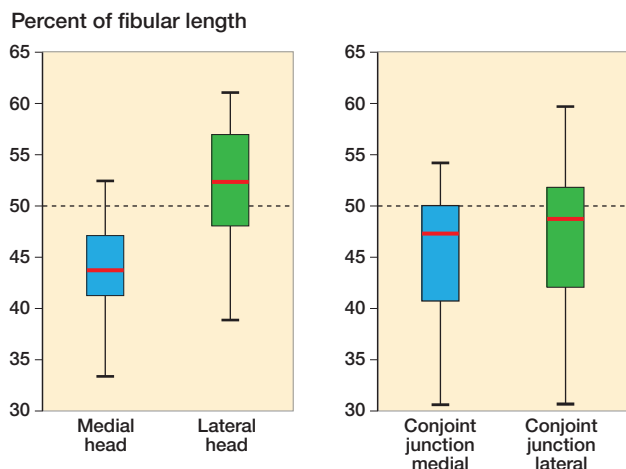


Figure 2. Median normalized location (with upper and lower quartiles, and ranges) of the medial and lateral muscular-tendinous junction and of the merge (conjoint tendon) of the gastrocnemius and the soleus as percentage of the fibular length.

medially at the MFRL. The median normalized location of the merge of the soleus to the medial head of the gastrocnemius and the lateral head of the gastrocnemius was at 47% (31–54) and 49% (31–60), respectively (Figure 2).

After dorsal or ventral fasciotomy, mean dorsiflexion angles with the knee in extension increased statistically significantly by 12°–19° ( $p < 0.05$ , Table 1). There was no statistically significant difference in increased dorsiflexion from baseline between the dorsal or ventral fasciotomy, nor in the amount of dorsiflexion after an additional dorsal or ventral fasciotomy. There was no significant difference between the mean gap size of 17 (14–19) mm after dorsal fasciotomy and of 14 (11–18) mm after ventral fasciotomy.

In 16 specimens, the route of the sural nerve was superficial to the fascia. In 4 specimens, the sural nerve was located deep to the dorsal fascia between the medial and lateral heads of the gastrocnemius. In 14 of the 20 specimens, the sural nerve followed the same route as the small saphenous vein.

## Discussion

From a surgical point of view, a gastrocnemius recession starts with finding the plane between the soleus and gastrocnemius muscle. Finding the plane can be challenging because of the wide variation in anatomy, as our study confirmed (Cummins et al. 1946, Elson et al. 2007). A long gastrocnemius aponeurosis would be easy to separate and lengthen. Our results show such a separate gastrocnemius aponeurosis/tendon on both sides in only 7 specimens. 3 specimens had a long (> 1 cm) gastrocnemius tendon at the medial side, and 3 specimens had the same on the lateral side. Consistent with our data (direct attachment in one-third of the specimens), Blitz and Eliot (2007, 2008) reported a direct attachment of the gastroc-

Table 1. Mean dorsiflexion angles before and after fasciotomy measured using the Silfverskiöld (1923) test

Measurement	Mean dorsiflexion angle (95% CI)	
	Knee in extension	Knee in flexion
Before fasciotomy	2° (-4 to 5)	15° (12–18)
After dorsal fasciotomy	21° (17–25)	23° (21–26)
After ventral fasciotomy	14° (8–20)	20° (18–24)

nemius aponeurosis to the soleus fascia in one-third of specimens, and Elson et al. (2007) reported a direct attachment in half and an asymmetry in the conjoint junction in one-third. This contrasts with the results of Hansen (2000), who reported that the gastrocnemius and soleus coalesced at the distal end. We confirmed the findings of Elson et al. (2007) and Blitz and Eliot (2007, 2008) that the conjoint junction varies widely in length and configuration. In most cases, the level of the fusion of the conjoint junction is proximal to the muscular-tendinous junction at the lateral side, which can make it difficult to find the plane between soleus and gastrocnemius and to perform the recession at the MFRL. Our study was performed in adult cadavers, and the results cannot be generalized to patients with cerebral palsy or other neurological conditions in which muscle bellies may be shorter and tendons longer.

We agree with Blitz and Eliot (2007, 2008), who stated that if there is a direct attachment of the gastrocnemius aponeurosis to the soleus muscle, tendon recession results in transecting the soleus aponeurosis or detaching the gastrocnemius muscle completely from its direct insertion, with potential loss of muscular power—and that a gastrocnemius recession in the muscle-bound portion is safer. They modified Baumann's multiple incision technique (Baumann and Koch 1989, Herzenberg et al. 2007) and renamed the procedure gastrocnemius intramuscular aponeurotic recession (GIAR), and also performed it at a more proximal transection zone with substantial muscle coverage of the medial and lateral gastrocnemius to avoid a full-thickness tendon muscle rupture. At this more proximal location, the muscle heads are more voluminous medially and laterally but not fused on the lateral side (Cummins et al. 1946, Elson et al. 2007). Thus, a more proximal recession makes the procedure easier because the gastrocnemius and soleus are easier to separate.

Alternatively, a straight posterior incision and dorsal tenotomy (Vulpinus and Stoffel 1913, Strayer 1950, Baker 1956, Hansen 2000) or posterior medial incision (Pinney et al. 2004, Chimera et al. 2012) with careful exposure of the superficial fascia and identification of the muscular-tendinous junction with retraction of the sural nerve could be a safer procedure than a blunt fasciotomy at the MFRL, but is not always feasible when the gastrocnemius recession is part of more complex surgery with the patient in supine position.

In our cadaveric specimens, an increase in dorsiflexion up to approximately 20° and a gap of 1–3 cm could be achieved

with a single incision (Table 1). Apart from being statistically significant, this increase in dorsiflexion is also clinically relevant, as it may correct many equine deformities in daily surgical practice. There was no need for multiple incisions as described in previous studies (Saraph et al. 2000, Herzenberg et al. 2007). The increase in ankle dorsiflexion after the recession is comparable to those described by Pinney et al. (2004) and Chimera et al. (2012), who reported increases of 18° and 14°, respectively. Our data for the gap size are consistent with those of Tinney et al. (2014), who used formaldehyde-preserved human cadavers. Formaldehyde increases tendon stiffness because of increased crosslinking of collagen and other proteins (Wilke et al. 1996). For the dorsal resection, Tinney et al. (2014) measured a mean gap of 15 mm, compared to ours of 17 mm. These measurements are slightly different from those of Firth et al. (2013), who described a 10- to 14-mm gap size in formaldehyde-preserved cadavers. Blitz and Eliot (2008) reported a gap size of 1–3 cm, which is comparable to our mean gap size of 14 mm.

Our third aim focused on the location of the sural nerve; we found that the medial cutaneous nerve, which forms the sural nerve together with the lateral cutaneous nerve, was predominantly located between both heads of the gastrocnemius muscles on the superficial posterior sural fascia, before descending to the lateral side—as has been described before (Webb et al. 2000, Mestdagh et al. 2001, Tashjian et al. 2003).

The present study shows that during a ventral gastrocnemius recession (Saraph et al. 2000, Blitz and Rush 2007, Herzenberg et al. 2007) through a medial incision at the MFRL, only the medial head of the gastrocnemius muscle is visualized, while the sural nerve (in a more lateral location) is not always easy to locate. A blind recession of the fascia at the MFRL puts the sural nerve at risk at the intramuscular septum (Herzenberg et al. 2007), as well as on the lateral fascia/tendon, where the nerve courses toward the lateral malleolus and is not protected by a muscle head as on the medial side (Figures 1 and 3). A more proximal recession avoids the risk of injuring the sural nerve between both heads of the gastrocnemius muscle and the descending course at the lateral side, and is therefore preferable.

Our study was limited by the small number of specimens; a larger sample would have allowed more confidence in the data. The strengths of the study were the use of fresh-frozen cadavers, which are more similar to live tissue than specimens preserved in formaldehyde. Moreover, our use of paired specimens allowed us to compare both ventral and dorsal surgical techniques in each cadaver.

In summary, a ventral recession of the gastrocnemius fascia at the MFRL through a medial incision places the sural nerve at risk on the lateral side. A ventral gastrocnemius recession proximal to the MFRL, where there is enough muscle coverage, will provide adequate lengthening (and increase in dorsiflexion) while reducing the risk of injuring the sural nerve,

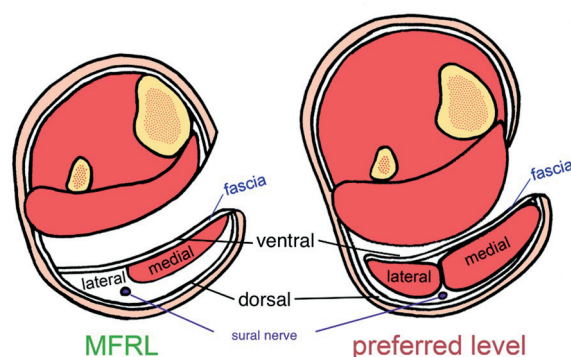


Figure 3 Transverse plane. Ventral gastrocnemius recession at the mid-fibular reference line (MFRL) (left), where there is no muscle protection of the sural nerve, and at the preferred level (right), where the medial head and lateral head of the gastrocnemius muscle protect the sural nerve.

incising the soleus muscle, or totally detaching the gastrocnemius muscle relative to a recession at or distal to the MFRL.

BS and EH were responsible for the study design, the dissections, and writing and revision of the manuscript. SB performed the statistical analysis. All authors finalized the manuscript.

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- Abbassian A, Kohls-Gatzoulis J, Solan M C. Proximal medial gastrocnemius release in the treatment of recalcitrant plantar fasciitis. *Foot Ankle Int* 2012; 33 (1): 14-9.
- Aronow M S, Diaz-Doran V, Sullivan R J, Adams D J. The effect of triceps surae contracture force on plantar foot pressure distribution. *Foot Ankle Int* 2006; 27 (1): 43-52.
- Baker L D. A rational approach to the surgical needs of the cerebral palsy patient. *J Bone Joint Surg Am* 1956; 38-A (2): 313-23.
- Barouk L S, Toullee E, Barouk P. Résultat de la libération proximale des gastrocnémiens. Étude prospective. *Méd Chir Pied* 2006; 22: 151-6.
- Baumann J U, Koch H G. Ventrale aponeurotische verlängerung des musculus gastrocnemius. *Oper Orthop Traumatol* 1989; 1 (4): 254-8.
- Blitz N M, Eliot D J. Anatomical aspects of the gastrocnemius aponeurosis and its insertion: a cadaveric study. *J Foot Ankle Surg* 2007; 46 (2): 101-8.
- Blitz N M, Eliot D J. Anatomical aspects of the gastrocnemius aponeurosis and its muscular bound portion: a cadaveric study-part II. *J Foot Ankle Surg* 2008; 47 (6): 533-40.
- Blitz N M, Rush S M. The gastrocnemius intramuscular aponeurotic recession: a simplified method of gastrocnemius recession. *J Foot Ankle Surg* 2007; 46 (2): 133-8.
- Chimera N J, Castro M, Davis I, Manal K. The effect of isolated gastrocnemius contracture and gastrocnemius recession on lower extremity kinematics and kinetics during stance. *Clin Biomech (Bristol, Avon)* 2012; 27 (9): 917-23.
- Cummins E J, Anson B J, Carr B W, Wright R R. The structure of the calcaneal tendon (of achilles) in relation to orthopedic surgery. *Surg Gynecol Obstet* 1946; 83: 107-56.
- DiGiovanni C W, Kuo R, Tejjwani N, Price R, Hansen S T, Jr., Cziernecki J et al. Isolated gastrocnemius tightness. *J Bone Joint Surg Am* 2002; 84-A (6): 962-70.

- Elson D W, Whiten S, Hillman S J, Johnson R J, Lo S S, Robb J E. The conjoint junction of the triceps surae: implications for gastrocnemius tendon lengthening. *Clin Anat* 2007; 20 (8): 924-8.
- Firth G B, McMullan M, Chin T, Ma F, Selber P, Eizenberg N et al. Lengthening of the gastrocnemius-soleus complex: an anatomical and biomechanical study in human cadavers. *J Bone Joint Surg Am* 2013; 95 (16): 1489-96.
- Hamilton P D, Brown M, Ferguson N, Adebibe M, Maggs J, Solan M. Surgical anatomy of the proximal release of the gastrocnemius: a cadaveric study. *Foot Ankle Int* 2009; 30 (12): 1202-6.
- Hansen S T. Tendon transfers and muscle-balancing techniques. In: *Functional Reconstruction of the Foot and Ankle*. Lippincott Williams & Wilkins: Philadelphia; 2000; 415-66.
- Herzenberg J E, Lamm B M, Corwin C, Sekel J. Isolated recession of the gastrocnemius muscle: the Baumann procedure. *Foot Ankle Int* 2007; 28 (11): 1154-9.
- Hoke M. An operation for the correction of extremely relaxed flat feet. *J Bone Joint Surg Br* 1931; 13 (4): 773-83.
- Maskill J D, Bohay D R, Anderson J G. Gastrocnemius recession to treat isolated foot pain. *Foot Ankle Int* 2010; 31 (1): 19-23.
- Mestdagh H, Drizenko A, Maynou C, Demondion X, Monier R. Origin and make up of the human sural nerve. *Surg Radiol Anat* 2001; 23 (5): 307-12.
- Pinney S J, Sangeorzan B J, Hansen S T, Jr. Surgical anatomy of the gastrocnemius recession (Strayer procedure). *Foot Ankle Int* 2004; 25 (4): 247-50.
- Saraph V, Zwick E B, Uitz C, Linhart W, Steinwender G. The Baumann procedure for fixed contracture of the gastrosoleus in cerebral palsy. Evaluation of function of the ankle after multilevel surgery. *J Bone Joint Surg Br* 2000; 82 (4): 535-40.
- Silfverskiöld N. The reduction of the uncrossed two-joints muscles of the leg to one-joint muscles in spastic conditions. 1923: 315-30.
- Strayer L M, Jr. Recession of the gastrocnemius; an operation to relieve spastic contracture of the calf muscles. *J Bone Joint Surg Am* 1950; 32-A (3): 671-6.
- Tashjian R Z, Appel A J, Banerjee R, DiGiovanni C W. Anatomic study of the gastrocnemius-soleus junction and its relationship to the sural nerve. *Foot Ankle Int* 2003; 24 (6): 473-6.
- Tinney A, Khot A, Eizenberg N, Wolfe R, Graham H K. Gastrosoleus recession techniques: an anatomical and biomechanical study in human cadavers. *Bone Joint J* 2014; 96 (6): 778-82.
- van Gils C C, Steed R H, Page J C. Torsion of the human Achilles tendon. *J Foot Ankle Surg* 1996; 35 (1): 41-8.
- Vulpus O, Stoffel A. Tenotomie der endsehnen der Mm. gastrocnemius et soleus. In: *Orthopädische Operationslehre*. Verlag Von Ferdinand Enke: Stuttgart; 1913; 29-31.
- Webb J, Moorjani N, Radford M. Anatomy of the sural nerve and its relation to the Achilles tendon. *Foot Ankle Int* 2000; 21 (6): 475-7.
- White J W. Torsion of the Achilles tendon: its surgical significance. *Arch Surg* 1943; 46: 784-7.
- Wilke H J, Krischak S, Claes L E. Formalin fixation strongly influences biomechanical properties of the spine. *J Biomech* 1996; 29 (12): 1629-31.