

Research Article

# The lateralization pattern has an influence on the severity of ankle sprains

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## Abstract

**Study design:** Descriptive study.

**Background:** Many risk factors contributing to ankle sprains have been studied in medical literature with coordination and balance being two of the major endogenous factors described. These are influenced by lateralization – a developmental and adaptive ability determined by the asymmetrical construction of the human brain, with cross-laterality referring to mixed limb dominance.

**Objectives:** To determine whether cross lateralization is a risk factor for the severity of ligamentous injuries in ankle sprains since no data is yet available on such correlation.

**Methods:** Two hundred forty-four patients with acute ankle sprains (136 men and 108 women) were prospectively evaluated between April 2006 and March 2009. The mean age was 30 (ranging from 18 to 76). Clinical and ultrasonographic examinations were performed on the study subjects. Laterality was then assessed by the Coren questionnaire and the AOFAS score was calculated. Patients with syndesmotic injuries and fractures were excluded from the study. Those qualified were divided into straight and crossed groups, according to their laterality type.

**Results:** One hundred forty-four patients displayed straight lateralization, while cross-laterality was found in 100 subjects. Patients in the crossed group experienced more multi-ligamentous injuries than those in the straight group ( $p = 0.02$ ). Following trauma, a higher AOFAS score was attributed to subjects that displayed a straight lateralization pattern, in comparison to subjects presenting with crossed laterality ( $p = 0.04$ ).

**Conclusion:** Crossed lateralization is associated with higher severity of ligament injuries in ankle sprains and may be considered a risk factor for calcaneofibular ligament injuries.

## Introduction

Ankle sprains are amongst the most common injuries of the locomotory system in athletes, constituting up to 34.3% of sports-related trauma [1]. Lateral ankle ligament lesions predominate in such injuries [2]. Literature provides a large number of studies on the risk factors contributing to their development [3-6]. Beynnon, et al. subdivided ankle sprain risk factors into exogenous and endogenous [3].

As for the exogenous risk factors, footwear used by athletes is of critical importance. High-heeled shoes or footwear containing air cells, increase the risk of ankle injuries. According to numerous authors, it is neither the position of sportsmen during a match nor the level of the game that contribute to the risk of these fractures [3,5]. However, some believe ankle sprains are prone to occur more frequently in

the later stages of the game, specifically during the second half or towards the end of the first half [7].

A previous sprain history is found to be the most crucial endogenous risk factor [5]. Pasanen, et al. showed that 47% of ankle sprains sustained by basketball players were recurrent [8]. This is because earlier sprains may extend the reaction time due to the neuroreceptor lesions induced by previous injuries [3]. Hosea, et al. also proposed the female gender as a risk factor, reporting the risk of primary sprains to be 25% higher in girls than in boys of the same age [6].

Others have mentioned laxity of the ankle joint to be another contributor to ankle injuries. However, as the results of clinical tests – both the anterior drawer test and the talar tilt test - are evaluated subjectively, the already-published studies on the influence of laxity on ankle sprains vary in results.

### More Information

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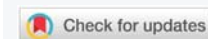
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Nonetheless, it is believed that a positive result of the anterior drawer test correlates with a higher incidence of sprains, while the talar tilt test does not allow for an unambiguous risk estimation [4].

Moreover, more frequent ankle sprains have been attributed to patients with increased body weight [9] and balance disturbances – most commonly measured as an inclination of the body's center of gravity on a dynamic platform [3], whereas balance training in athletes has been shown to reduce the occurrence of these injuries [10].

One of the endogenous factors influencing our coordination and balance is lateralization, a developmental and adaptive ability determined by the asymmetrical construction of the human brain. The majority of the human population has unilateral right-sided laterality: domination of the right eye (right-eyedness), hand (right-handedness), and leg (right-leggedness). Right-handedness is usually established by the age of 2-3 years while left-handedness is by the age of 3-4 years. Definite lateralization of motoric abilities is established by the age of 6. There are three models of lateralization: straight, cross, and unsteady [11].

Cross-laterality refers to both cerebral hemispheres exercising control over different organs. Thus, people with this kind of lateralization may have dominant organs on both sides of the body's lengthwise axis. They may, for example, be right-eyed and left-handed or right-handed, left-eyed and right-legged. This kind of mixed dominance may cause a number of problems, such as a tendency to distraction, difficulties in three-dimensional orientation, uncertainty in the determination of the left or right side of one's body, or even difficulties with decision-making. Moreover, they may suffer from disturbances of visual-motoric coordination, which – in turn – may cause problems in writing, reading, or performing motoric activities. Consequently, this may be aggravated by stress. Non-typical lateralization should not be of concern unless accompanied by any sort of dysfunction, e.g. motoric, visual, orientational, or secondary emotional disruption.

There are several psychological tests used to estimate laterality, including the "right-left" Piaget test [4], the Zazzo trial [12], or the handedness questionnaire developed by Oldfield [13]. In our study, the Coren questionnaire [11] was applied to assess handedness, leggedness, eyedness, and earliness by testing basic activities, such as writing, throwing, handling a tennis racket, kicking, etc. The dominant side is determined by a number of test scores.

To our knowledge, limited research has been carried out on the correlation between leg dominance and limb fractures but this is the first analysis of the influence of lateralization on ankle sprains and brain laterality being a potential risk factor for these injuries. The objective of our study was to evaluate the influence of laterality on the severity of ligamentous injuries in ankle sprains.

The results of this study are sent for publication now, but the research has been carried out in the years 2006-2009. The first author sets forth the explanation for the delay in publication: "I have spent the last several years developing my own orthopedic clinic, hence due to time and resource constraints I have been unable to publish my research.

## Materials and methods

The approval of the ethics committee was not required at the time the research was performed. All consecutive patients diagnosed with acute ankle sprains were prospectively evaluated between April 2006 and March 2009. After anamnesis, patients underwent standard clinical examinations comprising the talar shift and anterior drawer tests. The radiographic examination involved anteroposterior and lateral projections, and ultra-sonography of both ankles. The following inclusion criteria were applied: first-time, acute ankle sprain, no history of trauma of the involved leg, and an age above 18 years. Patients with systemic disorders, fractures, and syndesmotic injuries were excluded from the study group.

Data was collected from the study subjects on age, gender, and side of injury, the AOFAS score was calculated at [14] and laterality was assessed through the Coren questionnaire [11]. The patients were divided into two groups according to their laterality type. The first group was made up of subjects with a straight eye-hand lateralization (straight group), while the second group consisted of patients with a crossed eye-hand lateralization (crossed group). We decided to use eye-hand laterality as a parameter rather than eye-leg lateralization since 50% of the healthy population had not had an established laterality model for lower extremities.

## Statistical analysis

To statistically analyze results, the non-parametric equality test for two fractions and the chi-square Pearson's test were used with the  $p$  - value of 0.05 [15].

## Results

Two hundred forty-four patients were involved in the study (136 men and 108 women). The mean age was 30 years (ranging from 18 to 76 years). In 122 cases, the right ankle was sprained (60 women, 72 men), while in 112 - the left ankle (48 women, 64 men).

One hundred forty-four patients presented with straight- and one hundred displayed crossed lateralization, respectively.

The differences in the distribution according to gender are presented in Table 1 and have no statistical significance. The effects of the severity of injury examined with the ultra-sonographic examination are shown in Table 2.

## Influence of lateralization

Patients with cross lateralization experienced multi-



**Table 1:** Laterality type of the studied group according to gender.

|       | Straight Lateralization Group | Crossed Lateralization Group |
|-------|-------------------------------|------------------------------|
| Men   | 76                            | 60                           |
| Women | 68                            | 40                           |
| Total | 144                           | 100                          |

**Table 2:** Ligament injuries in ultrasonography according to laterality type.

|                | Number of patients | Injury            |                       |            |          |
|----------------|--------------------|-------------------|-----------------------|------------|----------|
|                |                    | Right Ankle       |                       | Left Ankle |          |
|                |                    | ATFL <sup>a</sup> | ATFL+CFL <sup>b</sup> | ATFL       | ATFL+CFL |
| Straight Group | 144                | 36                | 40                    | 28         | 40       |
| Crossed Group  | 100                | 12                | 44                    | 12         | 32       |
| Total          | 244                | 48                | 84                    | 40         | 72       |

<sup>a</sup>ATFL: Anterior Tibiofibular Ligament; <sup>b</sup>CFL: Calcaneofibular Ligament

ligamentous injuries more frequently than those with a straight lateralization pattern and this difference was statistically significant ( $p = 0,02$ ,  $\chi^2 = 5,35$ ). The ratio of single ligament injury to multi-ligamentous injury was 1.25 in the straight group and 3.17 in the crossed group, respectively (Table 3).

### AOFAS score results

The mean AOFAS score after trauma was 62. All AOFAS scores are presented in Table 4. A statistical difference between laterality groups was observed.

## Discussion

The influence of lateralization on movement precision, three-dimensional orientation, and correct writing is well known but, to our knowledge, no data on the effect of laterality on injury and trauma to the ankle has been published so far. Yet, several analyses of the influence of limb dominance on the incidence of locomotory system injuries are available.

Pekkarinen, et al. analyzed the correlation between the dominant hand and injuries and concluded that the risk of injury in the ambidextrous population is only insignificantly higher [16].

Ekstrand and Gillquist [5] found a considerably higher

**Table 3:** The severity of injury according to laterality type.

| Laterality type | ATFL <sup>a</sup> | ATFL+CFL <sup>b</sup> | ATFL+CFL / ATFL ratio                 |
|-----------------|-------------------|-----------------------|---------------------------------------|
| Straight Group  | 64 (44%)          | 80 (56%)              | 1.25                                  |
| Crossed Group   | 24 (24%)          | 76 (76%)              | 3.17 ( $p = 0.02$ , $\chi^2 = 5.35$ ) |

<sup>a</sup>ATFL: Anterior Tibiofibular Ligament; <sup>b</sup>CFL: Calcaneofibular Ligament

**Table 4:** AOFAS scores according to lateralization, age and gender.

| Varia       | Subgroups      | AOFAS score | p - value    |
|-------------|----------------|-------------|--------------|
| Laterality  | Straight group | 71          | $p = 0.04$   |
|             | Crossed group  | 57          |              |
| Gender      | Men            | 65          | $p > 0.05^*$ |
|             | Women          | 58          |              |
| Age (years) | 18 - 45        | 62          | $p > 0.05^*$ |
|             | > 45           | 53          |              |
| Side        | Right          | 59          | $p > 0.05^*$ |
|             | Left           | 64          |              |

\* Non-significant p - value

risk of ankle injury in the dominating leg in football players, observing that 92% of ankle injuries involved the dominant lower limb. This was further studied by DeLang, et al. who noted a higher incidence of injuries in the dominant limbs of soccer players [17]. Some authors believe that the dominant lower limb is at greater risk because of the higher demands and larger loads the majority of athletes place on them, while the non-dominant ankle has a more efficient protective mechanism due to greater flexor activity during excessive joint motion [18]. One study noted a 10-millisecond difference in latency of the peroneus longus muscle between both limbs, showing that the time it takes for the muscle to respond to ankle inversion is greater in the dominant limb [19]. As the peroneus longus acts as the primary active defense against lateral ankle injuries, greater latency in its activity increases the risk of sprains [19].

Noteworthy, findings of other authors – such as Beynnon, et al. [4] or Surve, et al. [20] - do not confirm the relationship between limb dominance and a higher risk of injury in football players, field hockey, or lacrosse players. When identifying the risk factors for hamstring muscle injuries, Freckleton, et al. did not find any significant differences between the dominant and non-dominant leg [21]. Potential reasons for this discrepancy could lie in the methodology of the studies and the complexity of ankle injury risk factors. A study by Mason, et al. suggests risk factors for ankle injuries might be unique for each gender – attributing a previous sprain history and higher BMI to male factors while correlating female ankle sprains with lower concentric dorsiflexion strength only [22]. According to their meta-analysis, only 20.2% of the pooled sample size constituted females, highlighting the lack of female-specific research and the discrepancy between the results for both genders.

Another limitation of the subject of our research is that limb dominance can be task-specific [23]. Similarly to limb preference, the superiority of one limb in a specific task does not exclude its inferiority in another – it is, therefore, possible that there is a discrepancy between the studies' chosen assessments for limb dominance and its influence on ankle injuries [24].

Moreover, no research has been found studying the influence of lateralization on accidental injuries. Kimmerle noted the lack of laterality data in research, mentioning reports rarely take into account the side of the body that was injured, disqualifying the possibility of body asymmetry being a risk factor for these injuries [25].

The objective of our study was to establish the influence of lateralization on locomotor trauma severity. We evaluated not only the effect of extremity domination but also, the impact of laterality on the severity of the injury. As lateralization is especially pronounced in the upper limb, the combination of eye and upper limb domination was used to divide the



examined population into “straight” and “crossed” lateralized groups. We did not evaluate the relationship between lower extremity laterality and the severity of the injury.

The type of trauma analyzed was that of ankle sprains. To maintain a uniform group, only patients with the most prevalent ankle sprain pattern were included, limiting the study to an anterior talofibular ligament (ATFL) and calcaneofibular ligament (CFL) ruptures. Any other injury patterns such as “high ankle sprains” were excluded.

Due to its high sensitivity and specificity in the assessment of ankle ligaments, ultrasonography was used to establish the number of ligamentous injuries. D’Erme [26] reported a concordance of 85% and 67%, respectively, between ultrasonographic examination and magnetic resonance imaging (MRI) in the diagnosis of ATFL and CFL damage. This is also supported by Milz, et al. [27] who found that ultrasound and MRI were concordant in 13 out of 14 damaged anterior talofibular ligaments and in all damaged calcaneofibular ligaments.

This study enabled us to examine the influence of the lateralization pattern on the severity of trauma to the ankle joint.

Patients with cross laterality suffered more severe ankle ligament injuries. Moreover, they performed worse in several clinical scores. Other factors influencing prognosis included age and sex - worse prognostic factors were attributed to women and people over 45 years of age.

Establishing a lateralization type may have practical implications. Our results suggest that more complex injuries and worse treatment results may be expected in patients with cross-laterality, potentially leading to additional diagnostic requirements and more intensive rehabilitation. In our view, establishing cross-lateralization may be a crucial prognostic factor.

## Conclusion

Cross-lateralization is associated with higher severity of ligament injuries in ankle sprains and may be considered a risk factor for CFL injuries.

### Key points

**Findings:** Patients with cross-lateralization experienced multi-ligamentous injuries more frequently than those with a straight laterality pattern.

The mean AOFAS score after trauma was significantly lower among subjects with cross lateralization.

**Implications:** More prevention exercises and longer rehabilitation protocols are recommended for patients with a cross-laterality pattern.

**Caution:** Our findings were based on clinical and ultrasonographic examinations.

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