Invited lecture/Scientific contribution

Arthrogenic Muscle Inhibition in Ankle Instability

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Abstract:
Ankle sprain is the most common injury among athletes and in the general population. A previous ankle sprain is a major risk factor for re-injury or the development of instability. Instability may be related to the neuromuscular changes after the injury. These include arthrogenic muscle inhibition (AMI), which is likely to be influenced by central regulatory mechanisms that lead to reduced muscle activation after injury. Our aim was to determine whether AMI is present in subjects after acute ankle sprain or in subjects with ankle instability. The literature search were performed in PubMed, Cochrane Library, EMBASE (Ovid) and Medline databases. We used a combination of English keywords. In addition, the literature lists of included studies were reviewed. Studies were screened regarding the inclusion and exclusion criteria. We included five studies investigating the presence of AMI in subjects with ankle sprain or /and instability. Statistically significant reduced activation of m. soleus was reported in four studies. In two studies, reduced activation of m. peroneus longus was reported, but only in subjects with ankle instability. Conclusions: We found that AMI, manifested as reduced activation of m. soleus and m. peroneus longus, is present in subjects with ankle sprain or instability. Inhibition is present bilaterally only in the acute phase. The mechanisms of AMI are most likely not only under local control, but also under central control.

Keywords: Ankle sprain; Ankle instability; Arthrogenic muscle inhibition

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1. Introduction

1.1. Ankle sprain and chronic ankle instability

Ankle injuries are the most common injuries in both athletes and general population (Doherty et al., 2014). A previous ankle sprain is an important risk factor for a re-injury (Hertel, 2002; McKay et al., 2001). Between 15 and 64% of people develop chronic or functional instability after an ankle sprain (van Rijn et al., 2008). This could be due to the mechanical or functional insufficiency of the structures of the injured joint, but research has shown that mechanical laxity of the joint is not necessarily present in people with chronic instability (Gribble et al., 2016; Gribble et al., 2014). Therefore, neuromuscular changes occurring at the time of or after the injury are thought to play an important role in the development of chronic ankle instability (Kim et al., 2019). These include, in particular, altered afferent sensory information from the joint to the central nervous system, which occurs due to damage to the ligaments in the joint and joint capsule (Freeman et al., 1965).

1.2. Arthrogenic muscle inhibition (AMI)

Arthrogenic muscle inhibition (AMI) is often an overlooked consequence of joint injury and is defined as the reflex inhibition of the intact muscles around the injured joint. AMI is thought to be a protective mechanism that protects the injured joint from increased stresses on the joint after injury, but the presence of AMI also makes rehabilitation more difficult (Hopkins & Ingersoll, 2000). AMI is not the same as atrophy and muscle weakness, but it means impairment of muscle activation or inability to develop maximal voluntary contraction. In the knee joint, AMI after injury or surgery has been shown to result in a reduced (voluntary) activation of the m. quadriceps femoris (Urbach et al., 1999; Urbach & Awiszus, 2002; Sonnery-Cottet et al., 2022), and a previous review of the literature has showed that muscle inhibition at the spinal cord level is also present in people with chronic ankle instability (Kim et al., 2019).

1.3. Muscle activity measurements

EMG measurements are used to determine the presence or absence of AMI. Among them, the H-reflex is observed, which assesses α-motor neuron's excitability (in response to the stimulation of sensory nerve). A change in the maximum H-reflex value (H_{max}) represents a change in the ability to activate the motoneuron (Palmieri et al., 2004). Lower H_{max} represents less muscle activation and therefore indicates the presence of AMI. Higher H_{max} represents increased activation or excitation. Usually, the H_{max} value is normalized by the M_{max} value, which represents the maximum possible activation of the whole motor neuron (direct stimulation of the α-motor neuron). Thus, the H_{max}/M_{max} ratio is reported in the results (McVey et al., 2005).

1.4. Purpose

The aim of this literature review is to determine whether arthrogenic muscle inhibition is present in subjects after acute ankle sprain or in subjects with ankle instability.

2. Methods

Literature was searched in PubMed, Cochrane Library, EMBASE (Ovid) and Medline databases. The last review was carried out on 7 December 2022. We used the following English keywords: ankle AND arthrogenic muscle inhibition. In addition, we have reviewed the reference lists of the included articles. Inclusion criteria was articles in English, population of subjects with ankle sprain or ankle instability, and EMG-measured muscle activity had to be reported during the outcomes. Studies that were not fully accessible, studies that simulated joint swelling and studies that did not observe the muscles around the ankle were excluded.

3. Results

After excluding duplicates, a total of 16 different studies were found. After screening and eligibility assessment, five studies published between 2004 and 2022 were included in the review (McVey et al., 2005; Palmieri-Smith et al., 2009; Klykken et al., 2013; Bowker et al., 2016; Kim et al., 2022).

The characteristics of the participants in the included studies are presented in **Table 1**. In all studies, the subjects were young adults.

Table 1. Characteristics of the participants in the included studies.

Study	Pathologies	Samples
Kim et al (2022)	Acute ankle sprain	n = 60, majority M
Klykken et al (2013)	Acute ankle sprain	n = 20, majortiy F
McVey et al (2005)	Chronic (functional) instability	n = 29, majortiy F
Palmieri-Smith et al (2009)	Chronic (functional) instability	n = 42, majortiy F
Bowker et al (2016)	Chronic instability	n = 93, majortiy F

M: males, F: females.

In four included studies (Kim et al., 2022; Klykken et al., 2013; McVey et al., 2005; Palmieri-Smith et al., 2009) the subjects were divided into two groups: subjects with present ankle pathology (experimental group – EG) and subjects without present ankle pathology (control group – CG). In those studies, H_{max} and M_{max} were measured in both lower limbs and in both groups. In the study by Bowker et al (2016) there were three groups: subjects with a history of ankle injury with instability (EG1), subjects with a history of ankle injury without instability (EG2) and subjects with no history of ankle injury (CG). In this study, measurements were taken only on the injured limb. Within group comparison has been done in four studies, comparing injured and uninjured side (Kim et al., 2022; Klykken et al., 2013; McVey et al., 2005; Palmieri-Smith et al., 2009) and in four studies, comparison between groups has been done (Kim et al., 2022; Klykken et al., 2013; Bowker et al., 2016). In three included studies activation of m. soleus, m. peroneus longus and m. tibialis anterior was observed (Kim et al., 2022; Klykken et al., 2013; McVey et al., 2005), in only one study (Palmieri-Smith et al., 2009) m. peroneus longus activity was observed and in only one study (Bowker et al., 2016) m. soleus activity was observed.

In all four studies reporting differences between the injured and uninjured leg within the control groups, there was no statistically significant difference in the H_{max} / M_{max} ratio (Kim et al., 2022; Klykken et al., 2013; McVey et al., 2005; Palmieri-Smith et al., 2009). In two studies (Klykken et al., 2013; McVey et al., 2005), the H_{max} / M_{max} ratio of m. soleus in the experimental group was statistically significantly lower in the injured leg as compared to the uninjured side, while Kim et al (2022) have not found any differences. In the experimental group, the H_{max} / M_{max} ratio was higher in m. tibialis anterior at the injured side than at the uninjured side in only one study (Klykken et al., 2013). In two studies (McVey et al., 2005; Palmieri-Smith et al., 2009), a statistically significantly lower H_{max} / M_{max} ratio was observed in the experimental groups for m. peroneus longus at the injured side compared to the uninjured side. The results of the comparison between sides within each group are summarized below in the **Table 2**.

Table 2. Within group comparison – injured and uninjured leg.

STUDY	m. soleus	m. peroneus longus	m. tibialis ant.
Kim et al (2022)	EG: / CG: /	EG: / CG: /	EG: / CG: /
Klykken et al (2013)	EG: SS ↓ H_{max}/M_{max} ratio on the injured side than on the uninjured side CG: /	EG: / CG: /	EG: SS ↑ H_{max}/M_{max} ratio on the injured side than on the uninjured side CG: /
McVey et al (2005)	EG: SS ↓ H_{max}/M_{max} ratio on the injured side than on the uninjured side CG: /	EG: SS ↓ H_{max}/M_{max} ratio on the injured side than on the uninjured side CG: /	EG: / CG: /
Palmieri-Smith et al (2009)	N/A	EG: SS ↓ H_{max}/M_{max} ratio on the injured side than on the uninjured side CG: /	N/A

EG: experimental group, CG: control group, SS: statistically significant, ↓: lower, ↑: higher, N/A: not available, /: not statistically significant changes.

The difference between groups has been observed in three studies (Kim et al., 2022; Klykken et al., 2013; Bowker et al., 2016). A statistically significant reduction in the H_{max}/M_{max} ratio of m. soleus in the EG compared to the CG has been reported in two studies (Kim et al., 2022; Bowker et al., 2016). In the study by Bowker et al (2016), there was a statistically significant difference when comparing the group of subjects with a history of injury and present instability (“non-copers”) with the group of subjects with a history of injury and no instability ("copers") as well as when comparing “non-copers” group to the control group (no history of injury).

Table 3. Comparison between groups.

STUDY	m. soleus	m. peroneus longus	m. tibialis ant.
Kim et al (2022)	SS ↓ H_{max}/M_{max} ratio in the EG than in the CG (both ankles compared to both ankles)	/	/
Klykken et al (2013)	/	/	SS ↑ difference between both ankles in the EG than in the CG.
Bowker et al (2016)	SS ↓ H_{max}/M_{max} ratio in EG1 compared to EG2 and CG. No SS difference between EG2 and CG.	N/A	N/A

SS: statistically significant, ↓: lower, ↑: higher EG: experimental group, CG: control group, /: not statistically significant changes, EG1: non copers, EG2: copers.

Additionally, there was no difference between the "copers" and control groups. However, in the study by Klykken et al (2013), there was no difference between EG and CG in m. soleus. Similarly, in neither of the studies that observed the activation of m. peroneus longus and compared the results between the two groups, there was a difference between EG and CG (Kim et al., 2022; Klykken et al., 2013). In the study by Klykken et al (2013) where they have compared the Hmax/Mmax ratio of the m. tibialis anterior between the two groups, the difference between the sides within the EG was statistically more significant than the difference within the CG. On the other hand, study by Kim et al (2022) did not report such difference. The results of the comparison between groups are summarized in **Table 3**.

4. Discussion

The results of the included studies suggest that the EMG-measured H_{max}/M_{max} ratio is reduced after an ankle sprain or in ankle instability in m. soleus and m. peroneus longus, indicating the presence of arthrogenic muscle inhibition.

It is assumed that the occurrence of AMI is not related to acute symptoms or specific changes at the local level, but to central mechanisms at the spinal cord level or even supraspinal level (Kim et al., 2022). Furthermore, findings from Palimieri et al (2004) indicated that all muscles around the joint showed facilitation rather than inhibition after simulated ankle swelling. In addition, the presence of bilateral inhibition of m. soleus, which was reported by Kim et al (2022), also suggests that central mechanisms are involved in the occurrence of AMI.

Bilateral inhibition seems to be present only after an acute ankle sprain, while in chronic ankle instability only unilateral inhibition of m. peroneus longus and m. soleus is present (McVey et al., 2005; Palmieri-Smith et al., 2009; Bowker et al., 2016). These results are consistent with the results of a previous meta-analysis by Kim et al (2019) that also confirmed the presence of unilateral muscle inhibition in subjects with chronic instability. In fact, it has been reported that m. soleus activation was reduced only in the subjects with a history of ankle sprain and presenting instability, but not in the subjects with a history of ankle sprain and no presenting instability (Bowker et al., 2016). This is consistent with the findings that ankle instability is not necessarily related to mechanical instability or increased joint laxity, but rather to neuromuscular changes that persist over time after injury (Gribble et al., 2016; Gribble et al., 2014, Kim et al., 2019). The presence of central mechanisms is also suggested in the study by Sedory et al (2007), where authors have reported ipsilateral inhibition of the quadriceps femoris and the knee flexors in subjects with chronic ankle instability.

The results of our review show the importance of appropriate management of ankle sprain and AMI after injury or in chronic ankle instability. By preventing and eliminating AMI, non-mechanical ankle instability could be prevented or reduced, which could lead to a lower incidence of re-injury. The impact of disinhibitory techniques such as cryotherapy and therapeutic exercise, which have been shown to reduce AMI after anterior cruciate ligament reconstruction in the study by Sonnery-Cottet et al (2019), should be tested in the future in the subjects after ankle sprain and in the subjects with chronic instability.

A limitation of our literature review is the small number of included studies and heterogeneity of population and methodologies. There are further studies needed to draw firm conclusions.

Based on the literature review, we found that AMI, manifested as reduced activation of m. soleus and m. peroneus longus, is present in subjects with ankle sprain or ankle instability. Inhibition is present bilaterally in the acute phase, and the mechanisms of AMI are more likely to be centrally controlled rather than locally controlled. Further research is needed to draw firm conclusions about the presence of AMI in ankle pathologies, including focusing on the potential for AMI reduction after injury or ankle instability.

Conflicts of Interest: The authors declare no conflict of interest.

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