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Masterclass

# New approach to the diagnosis and classification of chronic foot and ankle disorders: Identifying motor control and movement impairments

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ABSTRACT

The prevalence of foot and ankle (F&A) disorders is high. While chronic and recurrent F&A disorders are broadly documented in the literature, their underlying mechanisms have not been well defined. Currently, patho-anatomical, biomechanical and signs and symptoms (Si&Sy) models are widely used to diagnose and classify musculoskeletal F&A disorders. Within a multi-factorial bio-psychosocial framework, these models have limitations in identifying the underlying mechanisms that maintain chronic pain and disability. Therefore, a new approach to the diagnosis and classification of chronic F&A disorders is suggested in this Masterclass. This new approach is based on identifying the underlying mechanisms of the F&A disorder. This Masterclass aims to define and describe patterns of directional motor control and movement impairment of the F&A region based on the principal author's clinical observations. Such definition and description should lead to improved identification of consistent patterns. The basis of directional motor control and movement impairment patterns is proposed. As an example, one motor control and one movement impairment pattern is described in more detail. This Masterclass can be regarded as a prerequisite for future validation studies investigating the clinical applicability of adapting and implementing this novel classification system.

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## 1. Musculoskeletal foot and ankle disorders and current diagnostic models

The prevalence of foot and ankle (F&A) disorders is high. In a European study population of 70,497 subjects with foot diseases, the prevalence of orthopaedic conditions was 20.4% (Burzykowski et al., 2003).

Ankle ligament injuries occur frequently, with over two million individuals suffering trauma each year in the United States (Beynnon et al., 2001). Residual symptoms and recurrence are common (Kannus and Renström, 1991; Konradsen et al., 2002).

Despite the information on chronic and recurrent F&A disorders (Orava, 1994; Cooper, 1995; Renström and Konradsen, 1997; Konradsen et al., 2002; De Vera Barredo et al., 2007; Lentz et al., 2010), processes responsible for recurrence or chronicity have not been well defined.

For most chronic musculoskeletal disorders, a specific diagnosis is rarely achieved, frequently leading to a "non-specific" or "syndrome" classification. Therefore, the identification of underlying mechanisms is of particular importance. The tendency for pain and disability to persist in the absence of obvious, ongoing primary peripheral pathology is challenging (Zusman, 2002). The classification of chronic disorders into homogeneous groups and the application of specific interventions tailored to these groups may enhance treatment efficacy, as has been documented for other body regions (e.g., chronic low back pain (CLBP)) (O'Sullivan, 2005). This approach has not yet been applied to the F&A region. Therefore, the development of a new classification system for chronic F&A disorders, leading to more specifically targeted interventions, is justified.

The typical and commonly used diagnostic models for musculoskeletal F&A disorders are patho-anatomical, biomechanical and signs and symptoms (Si&Sy) models. Following is a description of these models and a discussion of their limitations with regards to the identification of possible underlying mechanisms for F&A disorders.

### 1.1. Patho-anatomical model

The patho-anatomical model is based on a traditional medical approach and aims to identify the structural pathology and/or pathophysiological processes responsible for the disorder. Within this model, examples of typical chronic F&A diagnoses are Achilles tendinopathy, plantar fasciitis and metatarsalgia. The aetiology of

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these disorders is often described as being multi-factorial (Järvinen et al., 2005; De Vera Barredo et al., 2007; Espinosa et al., 2010). Management within this approach often targets only the symptomatic structure(s). The evidence for the effectiveness of this approach when applied to the F&A region is often conflicting (Crawford and Thomson, 2003; De Vera Barredo et al., 2007; Kingma et al., 2007; Woodley et al., 2007).

Management targeting the symptomatic tissue in isolation does not consider the multi-factorial nature of the disorder and all underlying mechanisms, or the consequences of the chronic F&A pain condition. This might explain why no single treatment has been found to be superiorly effective in treating these common F&A disorders. It is therefore reasonable to argue that different mechanisms may lead to F&A pain, and it is crucial to identify a cluster of all underlying factors that maintain the patient's F&A disorder.

### 1.2. Biomechanical model

The biomechanical model has played a prominent role in the functional diagnosis of F&A disorders. Biomechanical variations of the F&A serve to explain different structural pathologies, overuse syndromes and tissue irritation or sensitivity in chronic disorders. Typically, biomechanical variations are related to structural characteristics of the foot, movement abnormalities of the F&A and the kinetic chain of the lower extremity.

#### 1.2.1. Structural characteristics of the foot and their correlation with pathologies and overuse syndromes

Conflicting evidence exists on the relationship between structural characteristics of the foot and pathologies or overuse syndromes, as is demonstrated by the examples below.

Giladi et al. (1985) demonstrated that a low arch of the foot was a protective factor against stress fractures, while Cowan et al. (1993) demonstrated a significant linear trend between increased arch height and increased risk of lower extremity overuse injury. Kaufman et al. (1999) found that men with either pes planus or pes cavus had an increased risk of stress fractures in the lower extremity.

This conflicting evidence could originate from the use of only non-weight-bearing (Giladi et al., 1985) or weight-bearing measurements (Cowan et al., 1993; Kaufman et al., 1999). None of the above-mentioned studies compared both conditions before determining the arch height. However, a patient with a flexible flatfoot will have a normal arch under non-weight-bearing conditions, but a substantial loss of arch height under weight-bearing conditions (Young et al., 2005). Weight-bearing position deficits of the foot do not necessarily correlate with structural characteristics in non-weight-bearing conditions.

#### 1.2.2. Movement abnormalities of the foot and ankle and their correlation with pathologies and overuse syndromes

A forefoot varus beyond 7° is associated with overpronation, potentially leading to Achilles paratendonitis (Kvist, 1991). Donatelli et al. (1999) found that forefoot varus angles above 12° lead to excessive pronation throughout the stance phase of gait. However, abnormal pronation was not found to be a significant contributing factor in the development of overuse injuries (Donatelli et al., 1999).

Research evidence suggests that decreased ankle dorsiflexion is a risk factor for Achilles tendon pain (Kvist, 1991; Kaufman et al., 1999; Cook et al., 2002). Markedly limited passive ankle joint dorsiflexion was found in 58% of athletes with Achilles tendon paratenosis and in 70% of athletes with pain at the Achilles tendon insertion (Kvist, 1991). Reduced ankle dorsiflexion is related to ankle sprains, both as a predictive factor and as a persistent post-traumatic impairment (Kannus and Renström, 1991; de Noronha et al., 2006; Pacey et al., 2010). Restricted dorsiflexion is also found in the symptom-free population. Kvist's study (1991) highlighted that 44% of the asymptomatic control athletes had markedly limited dorsiflexion of the ankle.

#### 1.2.3. Lower extremity kinetic chain principles and their correlation with pathologies and overuse syndromes

A biomechanical explanation for the association between movement abnormalities, consequent tissue strain and symptoms is often based on closed kinetic chain principles (Vogelbach and Combs, 1987; Ahonen, 1998). Based on these principles, within a closed kinetic chain, movement in one joint can result in movement in remote joints (Ahonen, 1998). For example, overuse injuries, such as patellofemoral pain or iliotibial band syndrome, can be related to biomechanical abnormalities remote from the specific symptom site (Wilder and Sethi, 2004; Souza et al., 2009). Some evidence exists for the inter-dependence of various alignment faults along the lower kinetic chain (Nguyen and Shultz, 2009). There is also emerging evidence of the coupling between F&A motion and lower limb transverse rotations (Souza et al., 2009). However, a relationship between static alignment, dynamic lower extremity function and injury risk remains rather theoretical (Nguyen and Shultz, 2009). Furthermore, within a kinetic chain model, human motion is considered a mechanical phenomenon, and other mechanisms regulating movement, motor control and pain mechanisms are ignored.

### 1.3. Signs and symptoms model

The signs and symptoms model is widely used within manual therapy. This model is often based on identifying movements that reproduce or reduce patient's symptoms, or identifying movement dysfunctions around the symptomatic region. Further differentiation between different musculoskeletal structures is accomplished with provocation testing. Any abnormal movement finding or symptom provocation can be considered a comparable sign (Maitland, 1986; Hengeveld and Banks, 2005). This model is further illustrated for the example of postero-medial ankle pain (Fig. 1) associated with sensitisation of the tibial nerve and excessive pronation of the F&A. These findings could be labelled comparable signs. However, identifying a sensitised structure does not explain the mechanism leading to sensitisation. Similarly, many different mechanisms may lead to excessive pronation of the F&A.

Within the Si&Sy approach, movement-based interventions will target the modification of symptoms by changing tissue response and/or normalising dysfunctional movements (Fig. 1). Evaluating possible underlying mechanisms for tibial nerve sensitisation and excessive pronation might demonstrate deficiencies in other contributing parameters (Fig. 1). The new classification system presented in this Masterclass paper proposes a targeted intervention approach to the underlying mechanisms that drive the disorder. It has been suggested that such an approach (versus interventions based on a Si&Sy approach) could change outcomes substantially (Elvey and O'Sullivan, 2004).

The Si&Sy model has been criticised before for its shortcomings (Elvey and O'Sullivan, 2004). While the model can be useful in identifying sensitised structures and movement dysfunctions, the underlying mechanisms of the F&A disorder might be overlooked. From this perspective, single tests and findings are not sufficient to identify the underlying mechanisms of the F&A disorders. Instead, a thorough examination process is recommended in combination with a clinical reasoning process that considers the interrelationship of all findings (Table 1).

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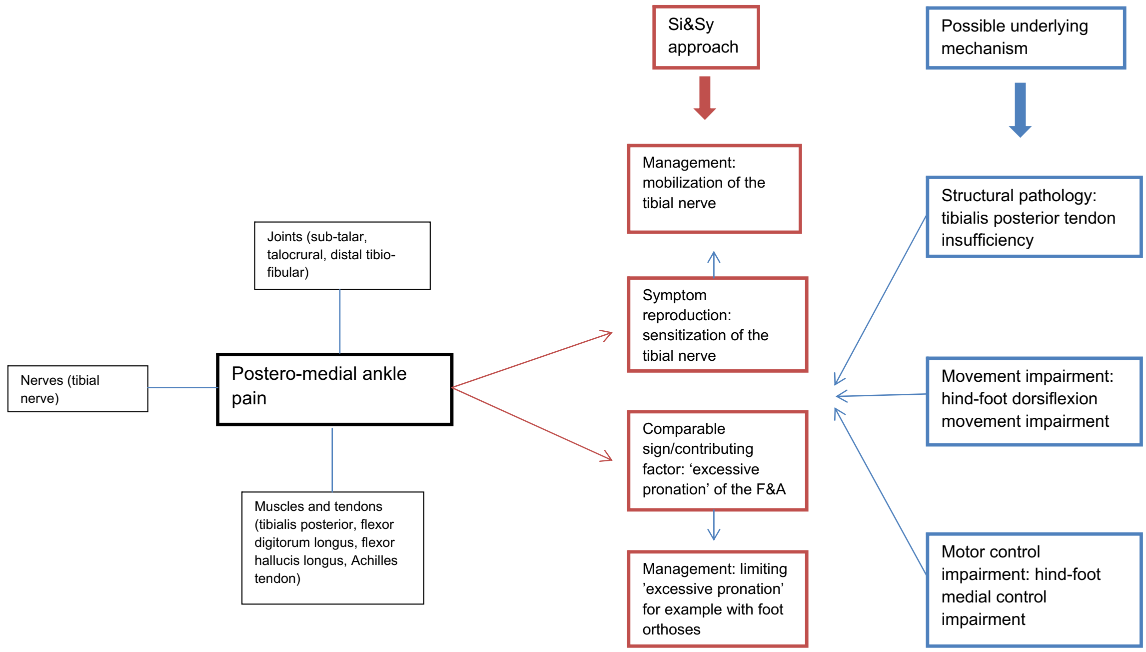


**Fig. 1.** Similar set of signs&symptoms (Si&Sy) caused by different underlying mechanisms. Identifying these mechanisms should lead to a more targeted management approach.

## 2. The basis for a new classification approach for chronic foot and ankle disorders

Current diagnostic models for F&A disorders fail to consider the underlying mechanisms of the disorders. Within a multi-factorial bio-psychosocial model, all factors that are maintaining the disorder should be considered. Without the identification of these mechanisms, an optimal treatment strategy for the patient's F&A pain disorder cannot be selected (Zusman, 2002). Based on this and the examples in previous paragraphs, a new approach for the diagnosis and classification of chronic F&A disorders is proposed in this Masterclass.

In this context, it is important to acknowledge that it is now well established that pain is a multi-dimensional, bio-psychosocial phenomenon (Linton, 2002; Zusman, 2002; Moseley, 2003). The role of biological, psychological and environmental factors in the aetiology, exacerbation and maintenance of chronic pain is supported by current theory (Turk and Wilson, 2010).

In a study of Finnish schoolchildren, the risk factors and consequences of traumatic and non-traumatic lower limb pain were dissimilar (El-Metwally et al., 2006). Traumatic lower limb pain was associated with vigorous exercise and a high level of physical fitness, while non-traumatic pain was more correlated with psychosomatic symptoms (El-Metwally et al., 2006). Psychological factors, such as emotions and cognition, can result in the release of chemical substances that are effective in sensitising spinal cord pathway neurons from the forebrain (Zusman, 2002).

Pain-related fear of movement, or kinesiophobia, has been shown to contribute to disability in F&A patients (Lentz et al., 2010). The way in which pain-related fear alters motor output and may further maintain the disorder has been described well (Linton, 2002). Furthermore, musculoskeletal pain tends to be recurrent, and the development of persistent disability is gradual. These gradual changes seem to be related to cognitive and learning factors (Linton, 2002).

Emerging evidence shows that psychosocial factors are related to chronic F&A pain disorders. It is hypothesised that the relative contribution of these factors to chronic F&A disorders is individual and requires separate screening.

Lifestyle factors, such as prolonged standing and obesity, have been related to chronic F&A pain disorders (Irving et al., 2006; Pensri et al., 2010). The F&A area has been identified as the most frequently affected body region among salespersons in department stores due to prolonged standing (Pensri et al., 2010). Furthermore, prolonged standing has been associated with the occurrence of chronic plantar heel pain (Irving et al., 2006). There is also evidence of an association between increased body mass index and chronic plantar heel pain (Irving et al., 2006).

Within this context, chronic F&A pain disorders should be considered within a multi-factorial framework and might demand a multi-dimensional management approach.

O'Sullivan's approach for CLBP disorders has highlighted the need for the classification of chronic disorders into broad subgroups based on the identification of the factors that drive a disorder. This approach takes into account the different underlying pain mechanisms of motor control and movement impairments and the directional basis of these impairments (O'Sullivan, 2005; Dankaerts et al., 2006, 2007), as well as mal-adaptive neuro-physiological, cognitive and lifestyle factors (O'Sullivan, 2005). Similarly, for chronic F&A disorders, such an approach should provide relevant information that is not derived from existing models.

## 3. A new approach to the classification of chronic foot and ankle disorders

### *3.1. Directional basis for motor control impairment and movement impairment patterns of the foot and ankle*

The F&A complex consists of a unique functional unit. Single joint movements occur around movement axes that are angled in distinctively different directions (Hicks, 1953; Wright et al., 1964; Hamill et al., 1995; Nester et al., 2001; Arndt et al., 2004; Tweed et al., 2008). Optimal function of the F&A is based on the synchronisation of individual joint movements, as the actions of the joints are highly inter-related, and an action at one single joint will influence other joints (Inman et al., 1981; Perry, 1992; Hamill et al., 1995; Nester et al., 2002). This complexity and

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**Table 1**
Clinical examination of the foot and ankle.

| Subjective examination | Examination in n-WB | Examination in WB | Functional tests | Observation of the gait | Active movements and muscle tests | Passive movement testing (joint provocation) | Provocation and screening tests |
|---|---|---|---|---|---|---|---|
| Kind of disorder | STJ in neutral position | Contact areas on ground | Standing with one leg | Timing relationship between movements | Active movements of the ankle | Sequential Mobility Examination of the F&A | Neural tissue |
| Symptom areas (s) | Alignment of the hindfoot | Alignment of the hindfoot | Squat<br>Squat with one leg | Compare gait pattern with functional movement findings | Active movements of the forefoot | Movements of the whole F&A (physiological) | Tendon tests |
| Behaviour of the symptoms<br>Pain behaviour | Alignment of the forefoot | Fleiss line | Rising on forefoot<br>Rising on forefoot with one leg | Observe impaired phase of the cycle | Active movements of the toes | Movements of the hindfoot and forefoot independently | Neurological screening |
| History of the symptoms<br>History of the pain behaviour | Mobility of the first ray and the I MTP | Contour of the medial longitudinal arch | *Rising on step<br>*Coming down from a step<br>*Jumping and landing | Observe compensatory movements | Specific muscle tests | Accessory movements of the joints of the hindfoot or forefoot | Vascular screening |
| Screening questions for RED and YELLOW FLAGS | Position of the second and third ray and mobility of II–III MTP | Contour of the lateral longitudinal arch | Functional demonstration (sports, dance) | Observe major determinants of the gait | | | |
| Questionnaire<br>Foot and ankle ability measure (FAAM)<br>Kinesiophobia Tampa Scale | Mobility of the fourth and fifth ray and IV–V MTP | DF of the I MTP and its influence on longitudinal arches and hindfoot alignment | *Independent activity of the forefoot<br>*Control of hindfoot neutral<br>*Dissociate forefoot and hindfoot control | *Observe gait on uneven surface<br>*Observe running | | | |
| | Callus formation | Compare n-WB and WB findings | | Compare functional tests and gait | | | |

Abbreviations: n-WB = non-weight-bearing, WB = weight-bearing, STJ = sub-talar joint, F&A = foot and ankle, MTP = metatarsophalangeal joint, DF = dorsal flexion.

variability of movements makes the clinical examination of F&A functioning extremely challenging.

In this Masterclass, pronation and supination (pro-sup) is defined as triplanar motions of the sub-talar joint (STJ) and mid-tarsal joint (MTJ) (Nester et al., 2001; Arndt et al., 2004). Eversion and inversion (ev–inv) are movements about an anteroposterior axis of the foot. Movements around this axis occur in the frontal plane (Arndt et al., 2004; Nester and Findlow, 2006). "Clinical setting" refers to what can be perceived in a clinical situation.

*3.1.1. Shortcomings of pronation and supination as motor control and movement impairment patterns*

In a clinical setting, hypothesis testing regarding F&A disorders often starts with analysing pro–sup movements. Pro–sup movement abnormalities are often associated with different F&A pathologies and overuse syndromes (Arndt et al., 2004). However, there are several difficulties in the clinical analysis of these movements. Motion of the forefoot relative to the hindfoot is a combination of motion at the STJ and at the MTJ, plus the motion within the navicular–cuboid–cuneiform–metatarsal complex (Nester and Findlow, 2006; Tweed et al., 2008). Analysis of the relative contribution of a single joint to the overall functional movement of the foot is difficult in a clinical setting.

From a biomechanical perspective, pro–sup movements occur in two different joints, namely the STJ and MTJ. The relative amount of movement in the STJ within a single movement plane and between different movement planes differs between individuals (Arndt et al., 2004; Kleipool and Blankevoort, 2010). Furthermore, frontal plane movement of the hindfoot occurs as a combined motion in both the STJ and the talocrural joint (TCJ) (Kleipool and Blankevoort, 2010). Based on recent studies, the MTJ is suggested to be capable of movement in all three cardinal body planes, either in isolation or in combination (Nester et al., 2001; Tweed et al., 2008). The predominant motion plane of the MTJ varies between subjects; some subjects have a predominance of frontal plane motion, and others have a predominance of transverse plane motion (Nester et al., 2002). Therefore, it is reasonable to hypothesise that movement at the MTJ is not limited to a single axis of rotation. Additionally, different movement variations within this joint will result in different loading patterns.

In a clinical setting, it is difficult to analyse the pro–sup movements of the STJ and MTJ because of combined motions with neighbouring joints. Also, impairment of pro–sup movement does not seem to correlate well with the site of symptoms or the loading area. For example, in the case of excessive pronation, symptoms can occur on either side of the ankle. Likewise, the forefoot can be in a supinated position, while the main loading area and related symptoms are medially under the first toe. Despite the attention given to increased or excessive pro–sup movements as a cause of F&A disorders, clinical and research evidence has failed to find consistent correlations between these movements and F&A pain disorders (Donatelli et al., 1999; Kaufman et al., 1999). However, the direction of loading that results from these combined hindfoot and forefoot movements can be identified.

Based on clinical application of this new approach, rather than excessive pro–sup movement being the cause of the F&A disorders,

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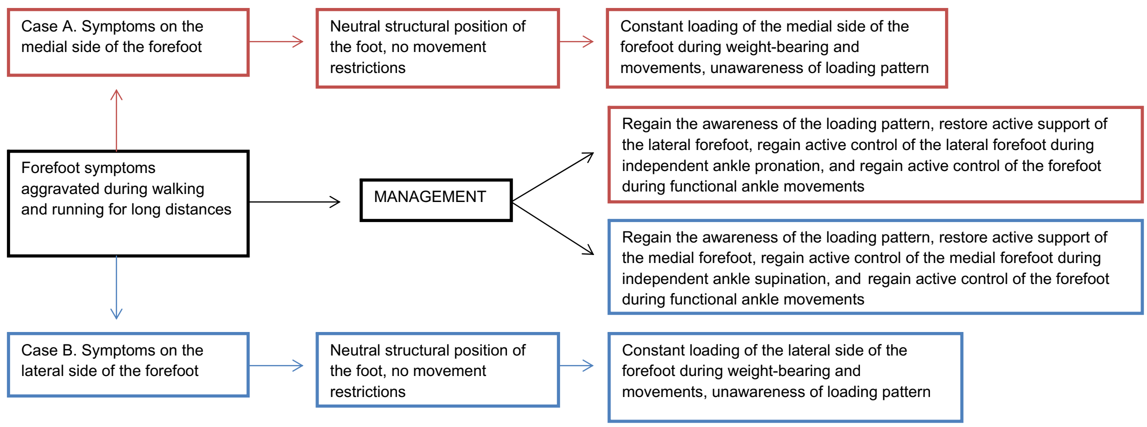


**Fig. 2.** Schematic illustration of the importance of identification of the 'direction of impairment' at the foot and ankle as a prerequisite for specific and individual intervention.

it appears that variability of movements can be lost due to motor control and movement impairments. In motor control impairments, lack of motor control results in monotonic loading patterns and pain in the F&A. In F&A movement impairments, movement is lost in the direction of pain provocation. Often, motor control and movement impairments appear to result in a loss of variable movements between the forefoot and hindfoot. Therefore, restoring motor control and variability of movements is a prerequisite for resolving the problem.

### *3.1.2. Shortcomings of eversion and inversion as motor control and movement impairment patterns*

Ev–inv movement of the hindfoot is a combination of STJ and TCJ motion. Furthermore, eversion is coupled with external rotation and inversion with internal rotation in both joints (Kleipool and Blankevoort, 2010). In STJ, the magnitude of these rotations and ev–inv motion is equal during the stance phase of gait (Arndt et al., 2004). In MTJ, ev–inv movements can be coupled in a different manner during the stance phase of gait. Between heel strike and forefoot loading, the MTJ can invert, adduct and dorsiflex, but it everts, abducts, and plantarflexes after heel-off. This illustrates the complex and variable functional characteristics of the MTJ (Nester et al., 2001). During the stance phase of gait, frontal plane movements of the MTJ occur in the opposite direction of the hindfoot (Tweed et al., 2008).

In a clinical setting, a full appreciation of the magnitude of ev–inv movement and its relevance within the coupled movements of the hindfoot and MTJ is difficult. However, a loading direction of the hindfoot and forefoot can be identified. For example, constant medial loading of the hindfoot or forefoot during functional movements is observable.

Similar to the pro–sup model, the ev–inv movement direction alone does not seem to correlate well with the site of symptoms, and no consistent correlation exists between movement direction and loading of the F&A structures. It appears that in motor control and movement impairments, the normal variability of ev–inv movements between forefoot and hindfoot is often lost.

The above-described shortcomings of movement models indicate that they are inadequate for classifying motor control and movement impairments of the F&A. The major problems include the following: 1) in a clinical setting, it is extremely difficult to analyse pro–sup and ev–inv during functional movements, 2) biomechanical outcomes do not necessarily correlate well with the site of pain and the loading patterns of the F&A, and 3) these movement models do not necessarily reflect abnormal movement patterns in chronic F&A pain disorders.

### *3.1.3. Identifying directional motor control and movement impairment patterns of the foot and ankle based on a patient's movement behaviour and resulting loading patterns*

Chronic pain disorders can change motor control around the F&A region and appear to result in monotonic movement and loading patterns, with specific parts of the F&A loaded unchangingly. Typically, these loading patterns present in a directional manner and are relatively independent of the movement task or activity the patient is performing.

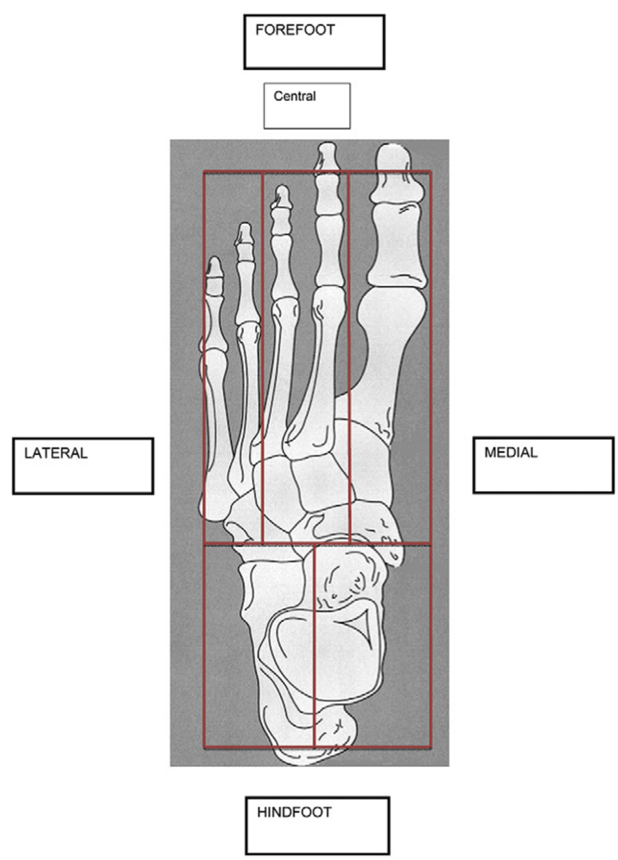


**Fig. 3.** Schematic illustration of the directional motor control impairment patterns of the foot and ankle.

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Identifying the direction of impairment is the basis for identifying the mechanisms involved in movement and motor control-related disorders of the F&A region. For example, a patient who avoids lateral loading of the hindfoot is likely to have a medially increased loading of the hindfoot. If this medially increased loading is interpreted as the underlying cause and an intervention is targeted to limit medial loading of the hindfoot, the F&A pain will persist. Attempts to limit medial loading of the hindfoot will evoke the patient's guarded movement pattern.

Identifying the direction of impairment is a prerequisite for planning and implementing a specific intervention. A clinical example of this is described in Fig. 2. In this figure, two patients with forefoot pain are presented with different directions of loading patterns that require different interventions.

The identification of directional motor control and movement impairment patterns is based on thorough clinical examination, combined with medical tests and screening questionnaires. The sequence of clinical examination used to identify motor control and movement impairments of the F&A is presented in Table 1.

The following F&A motor control and movement impairment patterns are based on observations of the principal author. These patterns have been tested in clinical practice and provide a new basis for evaluating chronic movement-based disorders and intervention for these F&A disorders.

| Forefoot medial control impairment | Hind-foot dorsiflexion movement impairment |
| --- | --- |
| *Subjective examination*: | *Subjective examination:* |
| Pain is locally in forefoot region medially.<br>Patient is avoiding activities that are aggravating the symptoms or they anticipate to aggravate the symptoms.<br>Patient is unaware of pain triggers – unawareness of loading patterns of the forefoot.<br>Patient experiences anxiety and lack of control related to the disorder.<br>Increased disability. | Pain is locally in ankle region.<br>Patient is avoiding dorsiflexion of the ankle and activities including intense dorsiflexion.<br>Patient is aware of pain or stiffness in dorsiflexion.<br>Patient is hyper-vigilant.<br>Patient is fearful of moving into dorsiflexion.<br><br>Increased disability. |
| *Observation in non-weight bearing and weight bearing:* | *Observation in non-weight bearing and weight bearing:* |
| In weight bearing contact area of the forefoot is predominantly medially.<br>The I MT is passively on the ground and/or the first toe is actively contracting on the ground.<br>Medial longitudinal arch is lowered.<br>Dorsiflexion of the I MTP joint and consequent plantar flexion of the first ray neutralizes the position of the foot and normalizes the contact areas of the forefoot. | In weight bearing F&A position is reflecting the compensatory loading pattern for dorsiflexion restriction.<br>Correcting the weight bearing alignment of the F&A restricts dorsiflexion of the ankle during squat. |
| *Functional tests*: | *Functional tests*: |
| In standing with one leg the balance is weakened on the symptomatic side. Patient supports monotonously on the medial side of the forefoot and loading of that area is increased. Again patient is unaware of this unchanging loading pattern.<br>During squat the same phenomenon is reinforced.<br>In rising on forefoot loading is still directed medially either on passive I MT or overactive first toe. | In standing with one leg the balance is weakened on the symptomatic side. Co-contraction type of muscle activity is often used to control the balance.<br>Dorsiflexion of the ankle is restricted during squat and high levels of muscle guarding are noted. |
| This leads to monotonous loading of medial forefoot structures, resulting in an ongoing tissue strain and peripheral sensitization. | This leads to increased compression of joints and movement restriction, resulting in an ongoing tissue sensitization. |
| Patient has difficulties to activate independently the I MT on the ground. They can not maintain the activity when hind-foot is supinated or pronated independently on forefoot.<br>They have difficulties to relax pretibial muscles and/or toe flexors. | *Gait:*<br><br>During late mid-stance and early terminal stance restricted ankle dorsiflexion is compensated. Compensatory movements are individual. |
| *Gait:*<br><br>During stance phase of the gait loading is maintained medially throughout the mid-stance and terminal stance.<br>In the end of terminal stance re-supination does not occur or it is delayed and independent movement between hind-foot and forefoot does not occur. | *Active and passive movements:*<br><br>Active dorsiflexion of the ankle is restricted.<br>Passive mobility examination reveals restricted ankle dorsiflexion and exaggerated withdrawal motor response.<br>Passive accessory movements are restricted. In dorsiflexion impairment typically restricted movements are STJ p/a and TC a/p. |
| *Active and passive movements:*<br><br>In active and passive movement testing there is no restriction in direction of pain. | |

**Fig. 4.** Features of forefoot medial control impairment and hindfoot dorsiflexion movement impairment.

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### 3.2. Describing motor control and movement impairment patterns of the foot and ankle

Mal-adaptive motor control and movement impairments are considered underlying mechanisms for chronic F&A disorders. Within these impairments, faulty movement patterns and coping strategies result in chronic abnormal tissue loading, pain, disability and distress. Different underlying pain mechanisms of motor control and movement impairments require further sub-classification. These impairments can present with or without patho-anatomical findings (O'Sullivan, 2005).

#### 3.2.1. Motor control impairments of the foot and ankle

In motor control impairments, lack of motor control drives the pain disorder. Pain provocation behaviour is characteristic of motor control impairments (O'Sullivan, 2005).

In motor control impairments, the F&A symptoms are related to the loading pattern at the symptomatic region. Typically, the patient complains of pain that has persisted beyond the expected tissue healing time and/or occurs without an identified pathology of the F&A region. Patients are unaware of pain triggers, and they might experience anxiety and lack of control related to the disorder. Patients avoid activities that aggravate symptoms, which will lead to disuse and increased disability. Often patients have had interventions based on single treatment modalities and/or general exercises, e.g., balance board training or stretching, with unsatisfactory outcomes.

Physical examination reveals unchanging and monotonous loading patterns of the foot. Loading in a standing position is predominantly directed toward the symptomatic region of the foot. Normal variability during active movements is diminished, and the symptomatic region of the foot is loaded unilaterally. It appears that patients are trying to enhance control of the F&A movements by loading the F&A in the same direction, independently from the task they are performing. Similar to patients with CLBP motor control impairments (O'Sullivan, 2005), these patients demonstrate this mal-adaptive, provocative behaviour consistently, but are unaware of it. Patients' pain is reproduced during functional tests, and it is related to an increased loading around the symptomatic region. During functional tests, monotonous muscle activity patterns are often noted and seem to be related to maintaining balance. Typical findings are increased static pre-tibial and/or toe flexor muscle activity. Correcting the weight-bearing position and movement alignment of the F&A often diminishes the symptoms immediately. During passive movement testing, there is no movement restriction in the direction of pain.

Based on the first author's clinical experience, five common and typical directional motor control impairment patterns of the F&A have been distinguished. Each pattern is named according to its direction of loading. The motor control impairment patterns are subdivided into medial, lateral or central and hindfoot or forefoot loading patterns. The most typical patterns are: hindfoot medial, hindfoot lateral, forefoot medial, forefoot lateral and forefoot central (Fig. 3). Fig. 3 is a schematic representation of the motor control impairment patterns. The squares reflect the sites of symptoms and the direction of loading.

As an example, the forefoot medial control impairment is described in Fig. 4.

Management of motor control impairments is based on an individual and specific motor learning intervention that addresses both physical and cognitive aspects of the disorder. The exercise intervention is individually structured to regain optimal function during patients' normal daily activities.

#### 3.2.2. Movement impairments of the foot and ankle

In movement impairments, loss of normal physiological movement drives the pain disorder. Movement impairments are characterised by pain avoidance behaviour (O'Sullivan, 2005).

Patients with movement impairment at the F&A will complain of chronic pain and/or stiffness in the F&A region. Symptoms are related to impaired movement direction. Patients often have an increased awareness of their F&A pain and the impaired movement direction that provokes the pain. As a consequence, the impaired movement direction becomes guarded, which contributes to an increase in stiffness. This can lead to hyper-vigilant behaviour in which patients pay increased attention to signals of threat. Increased fear and anticipation of pain will result in avoidance behavior, which in turn contributes to disability. Often, patients report aggravation of symptoms related to general exercises, such as balance board training, muscle training and stretching.

During active movements, patients avoid the painful movement direction associated with muscle guarding. Attempts to correct the movement alignment will result in increased impairment, protection and pain. In passive movement testing, a withdrawal motor response is exaggerated in the direction of impairment. These protective mechanisms are often anticipatory rather than an actual response to pain. Patients are apparently aware of the painful movement direction, and they are fearful of moving/loading in that direction. These findings in the F&A region are comparable with movement impairments of the low back (O'Sullivan, 2005).

Movement impairments of the F&A present in a directional manner and typically occur in four different directions. These directions are dorsal flexion, plantar flexion, medial, and lateral (Fig. 5). Fig. 5 is a schematic representation of movement impairment patterns. The squares reflect the direction of impairment.

F&A movement impairments seem to occur more often in the hindfoot than in the forefoot. However, the same directions can be used for forefoot impairments. As an example, the hindfoot dorsiflexion movement impairment is described in Fig. 4.

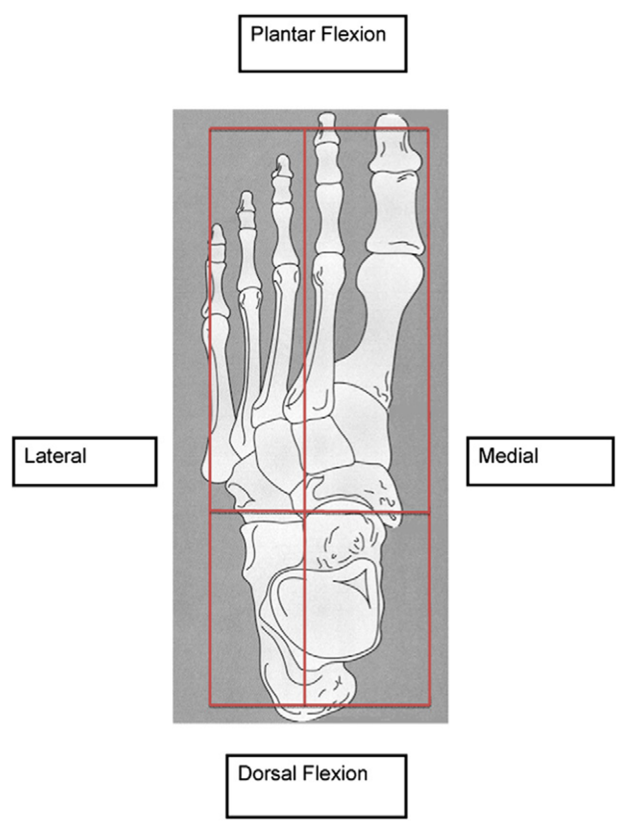


**Fig. 5.** Schematic illustration of the directional movement impairment patterns of the foot and ankle.

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Management of F&A movement impairments is based on an individual and specific educational and graded exposure program, including passive movement techniques, addressing both the physical and cognitive aspects of the disorder. The aim of this individual intervention is to restore normal physiological movement and motor control.

## 4. Summary

The classification of chronic F&A disorders into subgroups is critical to ensure appropriate management. Based on the extensive clinical experience of the principal author, an adapted version of O'Sullivan's classification system for CLBP is proposed for the F&A region. Motor control and movement impairments are two distinctive subgroups among chronic F&A disorders. Defining directional motor control and movement impairment patterns is a prerequisite for the classification system to be clinically useful for the F&A region. This Masterclass described this novel conceptual framework for mal-adaptive directional motor control and movement impairment patterns around the F&A region. Two examples of these impairments are described (Fig. 4) It is acknowledged that future research is required to investigate the inter-tester reliability of identifying these patterns. Laboratory-based studies are also essential to validate these patterns.

In patients with motor control and/or movement impairments, the patient's mal-adaptive movement behaviour is the underlying mechanism for the F&A pain. An analysis of all potential factors affecting this movement behaviour should be based on a comprehensive subjective and physical examination and should aim to identify the underlying mechanisms maintaining the chronic F&A disorders. Identifying this underlying mechanism also demands the integration of the proposed classification approach for F&A disorders within a clinical reasoning process.

In the F&A region, patterns of motor control and movement impairments present in a directional manner. Identifying the direction of these patterns of impairment is a prerequisite for individual and specific intervention. Both impairments require distinctively different management. Intervention for F&A motor control and movement impairments is based on addressing both the physical and cognitive aspects of the disorder.

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