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Escola Superior de Tecnologia da Saúde de Coimbra

Relationship Between Internal Derangement of Temporomandibular Joint and Changes in Body Posture

Master's Dissertation in Physiotherapy

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Dissertation submitted by Tiago Miguel Rodrigues Rocha to the Escola Superior de Tecnologia da Saúde de Coimbra do Instituto Politécnico de Coimbra for comply the necessary requisites to obtain the Master degree in Physiotherapy – Human Movement Specialization, performed under the scientific guidance of PhD. Maria António Castro, Associate Professor of the Escola Superior de Tecnologia da Saúde de Coimbra and co-orientation of PhD. Daniele Manfredini, Associate Professor of the University of Padova.

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"A nossa vida é toda ela feita de acasos.

Mas é o que em nós há de necessário que lhes há-de dar um sentido."

Vergílio António Ferreira

Abstract

Key-Words: Temporomandibular joint, internal derangement of temporomandibular joint, temporomandibular joint dysfunction, body posture.

Background: The presence of body posture changes among patients with temporomandibular disorders (TMD) has been a controversial issue in the literature, in which it supporters point out the muscular origin as the main etiological factors, mainly associated with postural changes in head. Due to this controversy, it is pertinent to check whether this relationship exists on the most common etiology of TMD, the disk displacement, which translates a biomechanical internal disorder of the temporomandibular joint (TMJ).

Objectives: Assess body posture changes in subjects with internal derangement of the TMJ when compared to subjects without this biomechanical dysfunction, characterize the patterns of the jaw movements and assess to the muscle activation during jaw movements.

Methods: 21 subjects with TMJ disc displacement (DD) (test group) and 21 subjects without any TMD (control group) was assessed for body posture changes through evaluation of several body segments by posturography and also was evaluated the postural balance reactions through the center of mass during jaw movements using a balance platform. For the characterization of the jaw movement patterns it was done a kinematic analysis during jaw movements (active ROM and path of the jaw). For the muscle activation during jaw movements it was evaluated the masseter, sternocleidomastoid and spinae erector muscles by surface electromyography (EMG).

Results Discussion: Both groups show forward head posture and extension of the cervical spine, not noticing any other significant body posture changes in subjects with DD, and if we had to see in detail, in general, subjects without TMD shows more body posture changes than subjects with DD. The pattern of jaw movements is similar in both groups, but in subjects with DD the closing movements are more instable than the opening movements, related to a less effective movement control to counteract the force of gravity and the disk displacement. The bilateral muscle activation during jaw movements is higher in subjects with DD, likely related to a less stable pattern of movement which leads in a higher muscle activation to guide the movement and ensure the best as possible articular stability.

Conclusion: The disk displacement with reduction should be viewed as part of a set of signs and symptoms that require an accurate musculoskeletal and psychosocial assessment towards an earlier diagnosis for reduction and control of the functional limiting factors. In this direction, it seems that the relevant set of limiting signs and symptoms deserve a particular attention by health care practitioners involved in the assessment and treatment of TMD, in order to define effective therapeutic options.

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1. Introduction

The TMJ moves approximately two thousand times per day, during movements inherent to speech, mastication, swallowing, yawning, etc., therefore, this it is the more used joint in the body (Arellano, 2002). It is part of the stomatognathic system, formed by several internal and external structures able to perform complex movements. Chewing, swallowing, phonation and posture depends on the function, health and stability of this joint to work properly (Quinto, 2000). When there is any disorder or derangement in this joint, temporomandibular disorders (TMD) may occur, defined as a heterogeneous group of pathological conditions affecting the TMJ, masticatory muscles and adjacent related structures (McNeill, 1997; Egermark, Carlsson and Magnusson, 2001; McNeely, Olivo and Magee, 2006; Manfredini, 2010; Jerolimov, 2009).

TMD are a set of joint and muscle disorders affecting the temporomandibular region, characterized by signs and symptoms such as pain and/or tenderness in the preauricular area and/or muscles of mastication, reduction and/or changes in mandibular range of motion, joint sounds like click and/or crepitus during jaw movements (Manfredini, 2010), decreased TMJ function, pain or muscle tenderness on palpation, pain during mandibular movement, facial pain and headache, classified as a subgroup of musculoskeletal disorders and rheumatologic in general (McNeill, 1997, Iwasaki et al. 2010; Moreno, Young, Yanaze and Cunali, 2002). Temporomandibular disorders are considered the most common orofacial pain condition of nondental origin (Manfredini et al. 2011). The frequent concurrent symptoms as sore throats, hoarseness, balance loss (Cooper and Kleinberg, 2007), earache, headache, neuralgia and tooth pain makes the assessment of TMD a complex issue (Leresche, 1997). From a psychosocial viewpoint, patients with chronic TMD report depressive symptoms, poor sleep quality, low energy and interference in social activity (Carlson et al. 1998; Manfredini et al. 2009; Manfredini et al. 2010; Tjakkes et al. 2010). Such aspects are worthy to be investigated by dedicated instruments, viz., the so-called axis II assessment, because of their importance in the clinical setting to predict treatment effectiveness.

Studies of incidence and prevalence of TMD indicates that 40-75% of adults referred at least one sign of joint dysfunction (joint noises, changes in mandibular movements, tenderness on palpation) and about 33% of the cases also reveal at least one symptom (facial pain, pain on mandibular movement, etc.) (Dworkin et al. 1990). Women aged between 15-40 years are more likely to seek for treatment due to TMD (Solberg, 1986; Egermark, Carlsson and Magnusson, 2001) with a ratio of 3-4:1 (Manfredini, Bucci e Nardini, 2007; Cooper e Kleinberg, 2007). An internal joint derangement, with a disk displacement toward an antero-medial direction, is the most frequent condition in subjects with TMD (Iwasaki et al. 2010; Carmeli, Sheklow and Bloomenfeld, 2001; Schiffman, Anderson, Fricton and Lindgren, 1992; Buranastidporn, Hisano and Soma, 2004; Tomas et al. 2007; Nitzan, 2001; Molinari et al. 2007; Palomar and Doblaré, 2007; Tanaka et al. 2008; Manfredini et al. 2011).

The body posture is defined as the relationship between a segment or body part with the adjacent segments, as well as the interconnections between all segments which compose the human body (Gonzales and Manns, 1996). A combination of all support structures to obtain maximum efficiency on static and dynamic balance with minimal overload and energy expense, is considered the ideal posture. Poor posture is seen as a faulty relationship between the different body segments, provoking an increased demand for adaptation to support structures and decreased equilibrium efficiency (Gagey e Weber, 2000).

Good posture is essential to get the appropriate sensory feedback necessary to know the spatial orientation of body segments (kinesthetic position) and to maintain body balance. Poor posture may be viewed as a risk factor for muscle and joint pain, particularly at the neck, shoulders, spine and knees due to the shortening of muscle fibers resulting from an imbalance in the musculoskeletal system. This may overload the joints and be related with degenerative changes of the articular surfaces, such as osteoarthritis (Swann, 2009).

Posture has a major role also to explain how an individual reacts to emotions and to identify some personality traits. People who have an erect posture are seen as more confident and outgoing, whereas a more bending posture indicates insecurity and depression (Swann, 2009).

The human body is a system of rigid segments and it is possible to determine their position through its location, orientation and articular configuration (Zatsiorsky, 1998). The posture of each individual is determined by muscle chains, fascias, ligaments and bone structures, interdependent each other, and covering the whole body (Marques, 2000). Posture is an effectiveness indicator of the biomechanics, balance and neuromuscular coordination (Magee, 2002).

Posture and balance cannot be separated because if posture is the relationship between a segment or part of the body with the adjacent segments, the balance represents the relationship between all the forces that acts in the human body, contributing in a major way for the posture and for the mechanisms of posture control (Montgomery and Connoly, 2003). The main mechanisms of posture control are the oculomotor apparatus (motion planning and avoid obstacles in your path), the vestibular system (detects linear and angular accelerations) and the proprioceptive system (composed of several types of receptors that determine the position and velocity of the body segments in space) (Winter, 1995; Simoneau, Ulbrecht, Derr and Cavanagh, 1995; Chessa, Capobianco and Lai, 2002). The posture control is a complex function involving the central nervous system for control (command), the afferent fibers of the peripheral nervous system for regulation and the musculoskeletal system to perform (effector) (Missaoui, Portero, Bendaya, Hanktie and Thoumie, 2008).

The human body is in equilibrium only if the sum of all forces and torques acting in this body are equal to zero; this rule is applied to both static and dynamic

balance according to Newton's second law (Knudson, 2007). The body posture is dependent on the perfect relationship between mobility and stability which determines the equilibrium state. This relationship, in turn, depends on the efficient weight distribution in the base of support, highly determined by the body segments characteristics (lenght and weight), which is usually referred to as "postural balance" (Knudson, 2007).

The postural balance is a condition in which all the forces acting on the body are combined into a single point called center of mass, and its vertical projection to the ground is commonly known as center of gravity (Winter, 1995). The uncoordinated action of external forces and internal forces can move the center of mass, requiring the action of the postural control mechanisms to restore balance and posture (Montgomery and Connolly, 2003).

The presence of postural changes among TMD patients has been occasionally described in the literature, with particular regard to postural changes in the head posture associated with pain in the head and/or in the cervical region, related with some peculiar facial morphologies.

Whereas the muscle action is responsible for the surface contacts of the TMJ, changes in head and body position may alter the response patterns of the muscles responsible for the jaw movement (Kimmel, 1994).

Some hypothesis attribute a major role to the posture in the onset of TMD symptoms, and claimed that factors such as an anterior position of the head (Munhoz, Marques and Siqueira, 2004; Janda, 1981) or premature contacts of the dental arch with subsequent potential asymmetric muscle functioning may be viewed as risk factors (Christensen and Rassouli, 1995).

However, the mainstream literature showed that occlusal features play a minor role in the etiology of TMD, so there is still some controversies on the issue, also because of the many healthcare professionals managing with TMD patients.

Currently in Portugal, due to lack of knowledge and training in the area, TMD is still seen as a purely dental problem, opting for treatments often very expensive, which do not solve the problem. Therefore, the first aim of this study is to inform and raise awareness among health care practitioners, about this condition. Often and depending on the patient's impairments, if they do not present referred or local pain, loss of function, altered sensitivity, social and/or psychological conditions, the most important treatment is information about its condition and counseling about some oral and leisure habits.

Specifically in terms of Physiotherapy, it is intended to make known an area little explored and underdeveloped, being increasingly necessary that the institutions of higher education recognize its importance and devote a section to TMD in their curricular plans, highlighting the fact that many studies attributing greater effectiveness

of the Physiotherapy when compared to other treatments (Toledo, Silva, Toledo and Salgado, 2012; McNeelly, Olivo and Magee, 2006; Carmeli, Sheklow and Bloomenfeld, 2001; Sato and Kawamura, 2008; Kalamir, Pollard, Vitiello e Bonello, 2007), and should be considered the treatment option, with a cost-effect relationship, more suitable.

The scientific aim of this study is to assess postural changes in subjects with internal derangement of the TMJ when compared to subjects without this biomechanical dysfunction. For this purpose will be evaluated several body segments by posturography and also will be evaluated the postural balance reactions through the center of mass during jaw movements using a balance platform.

Will also be an objective, characterize the patterns of the jaw movements. For that objective, a kinematic analysis of these movements (ROM and path of the jaw) will be performed and the activation of the masseter muscles, sternocleidomastoid muscles and spinae erector muscles, during jaw movements, will be evaluated by surface electromyography.

With this objectives and with the interest to find the answers to the questions/hypothesis: Subjects with disc displacement (DD) show active ROM in opening and lateral excursion movements, significantly different from individuals without DD?; Are there differences in the pattern of depression and elevation of the jaw in subjects with DD when compared to subjects without DD?; Is the total of displacement (in axes X and Y) for the movements of depression and elevation of the jaw, higher in subjects with DD?; Are there significant body posture changes at head level in subjects with DD when compared to subjects without DD?; Are there significant body posture changes in the generality of the body in subjects with DD when compared to subjects without DD?; Are there significant body posture changes between the right hemibody and the left hemibody in subjects with DD?; Are there significant body posture changes between the right hemibody and the left hemibody in subjects without DD?; Does the displacement velocity of the center of mass during the jaw movements, show significant differences between subjects with DD and subjects without DD?; Is the average path of COG during jaw movements, significantly different between subjects with DD and subjects without DD?; Are there significant differences in bilateral muscle activation of the Masseter muscles, Sternocleidosmatoid muscles and Spinae Erector muscles during jaw movements in subjects with DD?; Are there significant differences in bilateral muscle activation of the Masseter muscles, Sternocleidosmatoid muscles and Spinae Erector muscles during jaw movements in subjects without DD?; we set out to conduct this study, with the desire to provide the necessary information to health care providers who deal with TMD, so that they can more adequately develop their treatment targets, adapting their methods.

It is quite crucial that patients with TMD are evaluated as efficiently as possible. By the complexity and multiplicity of the etiology of this condition, there we focus the relevance of this study, in order to provide the necessary musculoskeletal relationships

to the treatment could be effective. We believe that with the data provided by this study, we can better determine the impairments of these patients and verify if body posture has a major role in patients with TMD, so that, the treatment could be oriented to meet the best benefits for the patient.

2. Literature Review

2.1 Temporomandibular Joint (TMJ)

The TMJ is formed by the temporal bone and the mandible, more specifically by the fossa and articular eminence of the temporal bone and the mandibular condyle. Between these two articular surfaces, a biconcave fibrocartilaginous disk adapts itself to provide the joint structures with stability during mandibular movements (Hlináková et al. 2010; Siéssere et al. 2008; Ingawalé and Goswami, 2009; Sommer et al. 2003).

Image 1: Temporomandibular joint movement during mouth opening.

Because the presence of this disk, the intra-articular space is divided into two cavities, the superior and the inferior compartments, also featuring the bilaminar zone (tissue with elastic fibers in the posterior region of the disk), the synovial membrane, the articular cartilage and the joint capsule (Hlináková et al. 2010; Siéssere et al. 2008; Ingawalé and Goswami, 2009). The extra-articular zone is composed by ligaments and muscles responsible for coordinating mandible movements along the different axes of motion. The main muscles acting on the TMJ are those of the mastication (temporalis, masseter, medial pterygoid and lateral pterygoid), and the digastric (Xu et al. 2008; Hannam at al. 2008; Siéssere et al. 2008). An equilibrium between the agonist and antagonist contractions of those muscles allows the best intra-articular stability, from which mandibular movements begin (Hlináková et al. 2010; Siéssere et al. 2008).

2.1.1 TMJ Anatomy and Biomechanics

TMJ provides a hinge movement in one plan, so it could be considered a trochoid or pivot articulation, but at same time provides sliding movement, characteristics of arthrodias or gliding joints (Koolstra, 2012). It has three degrees of freedom with each degree associated to an independent axis, enabling rotation and translation movements distributed through sagittal, frontal and transverse plans (Ingawalé and Goswami, 2009). The principal movements of this joint are an anterior rotation and translation (or sliding), whilst the other two possible movements the posterior and mediolateral translations (Nagerl et al. 1999). It is a synovial joint with the

joint capsule involving superiorly the fossa and articular eminence, and inserting inferiorly in the periosteum of the condyle branch (Hlináková et al. 2010; Siéssere et al. 2008; Ingawalé and Goswami, 2009). It also presents a peculiar feature, that is related with the articular surfaces are covered with fibrocartilage instead of hyaline cartilage, as is common in this type of joints (Hlináková et al. 2010; Ingawalé and Goswami, 2009). Typically, the fibrocartilage, because of its load-resistance properties to degenerative changes and best regenerating qualities, was mostly found in structures with high impact and repeated loadings (Norkin e Levangie, 2001).

The presence of the disk provides stability and consistency to the articular surfaces, distributes the forces over a larger area and spreads the synovial fluid, providing the lubrification and nutrition needed to the articular structures. The joint disk is composed of water, collagen, proteoglycans, elastin, fibrocartilage and chondral cells (Chin, Aker and Zarrinnia, 1996). The anterior part of the disk attaches to the articular eminence, to the condyle head and to the joint capsule, while the posterior part, which is highly vascularized and composed mainly of loose connective tissue, attaches to the bilaminar zone and to the joint capsule. In the lateral and medial levels the disk is closely attached to the joint capsule and to the condyle head, whilst the anteromedial plan it attaches to the superior part of the lateral pterygoid muscle (Willard, Arzi and Athanasiou, 2011; Sommer et al. 2003; Siéssere et al. 2008).

In the posterior region of the disk, attached superiorly to the retrodiscal space of the mandibular fossa and inferiorly to the condyle, is located the bilaminar zone, also generically known as "retrodiscal tissues", composed of collagen, elastic fibers, numerous blood vessels and nerves (Siéssere et al. 2008; Tanaka et al. 2002). The characteristics of the bilaminar loose tissue allow a wide range of motion to the disk, and prevent those tissues' dislocation during mouth opening (Sommer et al. 2003). With the jaw in the closed mouth position the retrodiscal tissue is organized into a dense network behind the condyle; with progressive jaw opening, this elastic tissue expands in all directions (Tanaka et al. 2002).

2.1.2 Biomechanics of Mandibular Movements

The functional dynamics of the jaw is obtained through a complex combination of intra-articular movements (condyle-disk; disk-eminence; attachments of the disk) with extra-articular movements (muscles and ligaments). Such coordinated actions result in mouth opening (jaw depression), mouth closing (jaw elevation), projection of the chin forward (jaw protrusion), slide the jaw backwards (jaw retropulsion) and sliding jaw on both sides (right and left lateral excursions) (Norkin and Levangie, 2001; Baskan and Zengingul, 2006). The normal range of motion for jaw movements is usually set between 40 and 55 mm for mouth opening and at least 7 mm for lateral excursions and protrusion (De Leeuw, 2008).

Another peculiar feature of the TMJ is that the action of the joints of the two sides is mutually interacting, since any movement that happens in one joint will

necessarily influence the movement in the contralateral side (Palomar and Doblaré, 2006); if the movements are identical in the two joints, the jaw movement is considered symmetric (Kang, Updike and Salathe, 1993).

With the jaw in the resting position, the condyle rests on the articular fossa of the temporal bone. For the mouth opening to occur it is necessary that a complex combination of rotation in the inferior space (condyle-disk) and sliding in the superior space (disk-fossa) happens (Gallo, Brasi, Ernst and Palla, 2006). In an healthy joint, mouth opening is determined mainly by the condyle rotation. The rotation in the inferior space involves a movement of the condyle with the disk attached to its bone surface. The disk follows the movement sliding relative to the superior space, and only a continuous condylar rotation can allow complete mouth opening (Ferrario, Sforza, Lovecchio and Mian, 2005). If load occurs in the mouth closed position, the disk deformation happens mainly in the central area, but if there is a sliding of the condyle forward (protrusion or begining of the mouth opening), the disk deformation tends to be in the lateral region, suggesting that certain regions of the disk suffer more loads than others (Beek, Koolstra and van Eijden, 2003).

In the case of the opening-closing movement, the condylar movements of the two sides are ideally symmetrical, whilst for the lateral excursions the condyles should perform asymmetrical movements. When the jaw makes a lateral excursion to the right side, the contralateral condyle (left) performs forward sliding until the articular eminence, while the ipsilateral condyle (right) remains in the articular fossa only performing a slight sliding movement to the same side of excursion (Koolstra and van Eijden, 1999).

The biomechanics of the human mandible can be explained as a complex model where several forces acted in combination to determine the resultant vector, such as muscle forces, inertial forces and reaction forces of the skull to the joints and to occlusion plans (Koolstra and van Eidjen, 1997). The jaw movement is accompanied by several muscles and by a large number of fibers of the same muscle, particularly from the muscles of mastication and although these muscles can be activated independently, each of one may influence more than one degree of freedom, where an combined contraction generates a resulting force and a resulting torque in relation to the gravity center of the jaw (Koolstra and van Eidjen, 1999). The muscle action is often described as the production of a torque to one or more joints, but in the human masticatory system the range of motion is not limited by the passive structures. It is for one force production limitation of the involved muscles, therefore, the muscle action is essential to the mandibular movement and to maintain joint stability in the midline during jaw movements (Pileicikiene and Surna, 2004). The passive structures such as ligaments, are essential only when the jaw reaches its mobility limits, acting as stabilizers in the outside of the midline movements, preventing the joint dislocation (Koolstra, 2002).

The primary muscle responsible for mandibular depression is the digastric. Electromyographic recordings showed a minor role of the lower portion of the lateral pterygoid too. The main muscles involved in jaw closing are the masseter, temporalis and medial pterygoid, even if the upper portion of the lateral pterygoid is also important because of its stabilizing action of the disk over the condyle. The masseter, medial pterygoid and lateral pterygoid are responsible for mandibular protrusion and the posterior fibers of the temporalis are responsible for retropulsion, also featuring a mild intervention of the digastric and suprahyoid muscles. The lateral excursions, unlike previous movements, are the only movements during which muscle contraction is not bilateral or symmetrical: an isolated contractions of the medial pterygoid or lateral pterygoid muscles may perform this movement, and if there is a contraction in ipsilateral muscle synergy of the lateral pterygoid and temporalis, it is also possible obtain an effective lateral excursion (Norkin and Levangie, 2001; Xu et al. 2008). A study of Koolstra and van Eidjen stated that the jaw opening muscles (digastric and lateral pterygoid) are not able to make this move over 3.3cm of distance between the incisors. In this position these muscles appears to be overly shortened and no longer with remaining strength to counteract the passive forces of the jaw closing muscles. The muscles responsible for jaw closing (masseter, temporalis and medial pterygoid) are much stronger than the jaw opening muscles and furthermore, the jaw opening muscles cannot produce passive forces able to counteract the jaw closing muscles (Koolstra and van Eidjen, 1997).

The ligaments composing the TMJ are the triangular, the sphenomandibular and the stylomandibular. The triangular ligament has an external portion which inserts in the condyle branch and an internal portion which inserts in the lateral region of the condyle and in the posterior region of the disk. This ligament acts as a strong lateral stabilizer inhibiting the posterior sliding of the mandible (Norkin and Levangie, 2001; Siéssere et al. 2008).

2.2 Etiology of Temporomandibular Disorders (TMD)

The etiology of TMD includes many factors, including occlusal, genetic, physiological, traumatic, pathological, social, psychological and developmental (Okeson, 1997). The combination of those factors can determine pathologies which can be divided into intra-articular (intracapsular): derangement of the complex condyle-disk (disk displacement, structural incompatibility of the articular surfaces); inflammations, adhesions and/or other injuries in capsule, in disk attachments, in articular cartilage; TMJ degenerative diseases (osteoarthritis, osteoarthrosis, ankylosis); and extra-articular (extracapsular): changes in the muscles of mastication (protective co-contraction, myofascial pain, muscle spasm, tendonitis) and TMJ ligaments; trauma (fracture); growth disorders (hypoplasia, hyperplasia, neoplasia, congenital malformations); systemic diseases (poliarthritis, chondromalacia); metabolic diseases and infections (De Leeuw, 2008).

Over the past decades, several purported malocclusions (skeletal class malocclusion I, II, III, posterior crossbite, anterior openbite, horizontal overlap, vertical overlap) were considered as a major cause of TMD based on the hypothesis that they can determine muscle hyperactivity that can exitate in TMD . Actually, evidence-based data suggested that the role of occlusal features as risk factors in the development of TMD is less important than believed in the past (Goldstein, 1999; Mohlin et al. 2007; Bonjardim et al. 2009; Manfredini and Lobbezoo, 2010).

The biopsychosocial theory is now the most widely accepted framework to assess temporomandibular disorders, and it postulates that the TMJ intra-articular and extra-articular etiology is complex and multifactorial, being directely dependent on predisposing, precipitating, perpetuating and contributing factors (Laskin, 1969; Greene, 1995; Suvinen et al. 2005).

Based on these concepts, it is likely that knowledge on TMD etiology will be strongly improved in the near future thanks to researches focusing on the triangle of factors composed by bruxism, pain, and psychosocial factors. On that purpose, several recent works by Manfredini and colleagues contributed a lot to get deeper into the issue (Manfredini and Lobbezoo, 2009; Manfredini, Cantini, Romagnoli and Bosco, 2003; Manfredini, Landi, Fantoni, Segù and Bosco, 2005; Manfredini and Lobbezoo, 2010; Manfredini, Peretta, Guarda-Nardini and Ferronato, 2010; Manfredini, Fabbri, Peretta and Guarda-Nardini, 2011).

Bruxism is an oral motor disorder characterized by grinding and/or clenching of the teeth with features in waketime (awake bruxism) and/or during the sleep (sleep bruxism) (De Laat e Macaluso, 2002). It is considered the most harmful parafunctional activity to the stomatognathic system, causing tooth wear and contributing as a major risk factor for TMD development (Manfredini and Lobbezoo, 2009). However, it is necessary differentiate awake bruxism and sleep bruxism because their pathogenesis as well as their potential consequences on the stomatognathic structures are different. The typical activity of awake bruxism is the clenching, while the sleep bruxism activity presents a combination of grinding with clenching (Manfredini and Lobbezoo, 2009). At a neurological level, this two types of bruxism also exhibit considerable diferences. During awake bruxism the clenching activity seem to be the result of emotional stress or psychosocial involvement, compelling the subject to make a prolonged contraction of the masticatory muscles (Manfredini and Lobbezoo, 2009); sleep bruxism is related to changes in central nervous system (Kato, Thie, Montplaisir and Lavigne, 2001; Kato et al. 2003) during deep sleep, accompanied by gross body movements, appearance of K complexes in electroencephalogram, increased heart rate, respiratory disorders, peripheral vasoconstriction and increased muscle activity (Kato et al. 2003; Huynh et al. 2006). The awake bruxism can be associated with psychosocial and psychopathological factors with no evidence linking the sleep bruxism with this same factors (Manfredini and Lobbezoo, 2009). Also, it must be remarked that bruxism is not a disorder per se,

since in some patients it may be viewed as an attempt to restore the physiological airway patency and avoid apnea episodes.

2.2.1 TMJ Internal Derangement

Internal derangement of the TMJ is defined as an abnormal mechanical relationship of the disk in relation to the condyle and mandibular fossa, with interference in the normal (functional) movement of the jaw (Maydana et al. 2010; Molinari et al. 2007). This abnormal relationship is clinically characterized as disk displacement (Tanaka et al, 2008; Manfredini, 2009; Nitzan 2001; Maydana et al. 2010; Palomar and Doblaré, 2006), causing joint pain, joint sounds, muscle tenderness and limitation of mouth opening (Nitzan, 2001; Tanaka et al. 2008). According to Truelove and colleagues, the TMJ internal derangement can be classified into three types: internal derangement type I (disk displacement with reduction); internal derangement type II (disk displacement with reduction and blocking episodes); internal derangement type III (disk displacement without reduction) (Truelove, Sommers, LeResche, Dworkin and vonKorff, 1992).

The etiological or risk factors for internal derangement, such as traumatic events, joint hypermobility (ligamentous laxity), degenerative diseases, occlusal factors, anatomy of the articular eminence and the role of the lateral pterygoid muscle (Isberg and Westesson, 1998; Gokalp, Turkkahraman and Bzeizi, 2001; Loughner et al. 1996; Molinari et al. 2007; Manfredini, 2009; Nitzan, 2001), have been controversial. Current theories suggested that the mechanisms which cause friction and repetitive loads (mandibular condyle) causing defects in joint lubrification, represent the role major in disk displacements (Manfredini, Basso, Salmaso e Guarda-Nardini, 2008; Tanaka et al. 2008; Nitzan, 2001; Manfredini, Basso, Arboretti and Guarda-Nardini, 2009; Gallo, 2005; Palomar and Doblaré, 2007; Spilker, Nickel and Iwasaki, 2009; Gallo, Nickel, Iwasaki and Palla, 2000; Tymofiyeva et al. 2007; Harper and Schneiderman, 1996). In the healthy TMJ the friction coefficient is around 0.0145-0.0239 (Tanaka et al. 2008), and if there is an excessive increase of this ratio, it may reduce the fluency of mandibular movements and facilitate the processes leading to changes in the condyle-disk relationship (Manfredini, 2009).

The term “disk displacement” implies that there is a previously normal or physiological position of the disk (Manfredini, Basso, Salmaso and Guarda-Nardini, 2008). The ideal relationship of the disk with the condyle in mouth closing position is known as the “12 o’clock position”, in which the posterior band of the disk is over the higher portion of the condyle (Stegenga, 2001; Tasaki et al. 1996). Any other anteriorized position of the disk with respect to the above one is usually clinically associated with the typical click sound, indicating disk displacement (Manfredini, Basso, Salmaso and Guarda-Nardini, 2008; Emshoff, Brandlmaier, Bertram and Rudisch, 2002).

Disk displacements may be with reduction or without reduction (McNeill, 1997; Okeson, 1997; Schiffman, Anderson, Fricton and Lindgren, 1992; Dworkin and LeResche, 1992).

Disk displacement with reduction is characterized by a temporary displacement, where the disk tries to regain its relationship with the condyle during condylar movement, thus resulting in a joint sound (click) on opening. During closing a reciprocal click usually occurs, although this is of lesser magnitude, corresponding to the anterior or anteromedial displacement of the disk. In the disk displacement without reduction the relationship of the disk with the condyle is permanently disturbed, since the disk remains in an anterior position with respect to the condyle throughout the whole condylar traslation. This condition is not usually accompanied by any joint sounds, but a limitation in the jaw range of motion with a deflection toward the affected side is clinically detectable (McNeill, 1997; Palomar and Doblaré, 2007). However, the displacement of the disk without further limitating conditions for the subject (referred or local pain, loss of function, altered sensitivity, social and/or psychological conditions, etc.), is not considered a pathological marker by itself (Manfredini, 2010), even if it represents only a risk factor for further degeneration of the joint surfaces. As the movements of the condyle are dynamic and continue to transmit loads, friction and shear forces induced on the disk will increase, leading to a worsening state of the internal derangement, the disk can begin to deform, adopting a biconvex form, becoming more long and thin, until may even suffer cracks and be perfurated (Palomar and Doblaré, 2007; Molinari et al. 2007). The evolution of disk displacement appears to be related with poor load distribution and biomechanical failure of the TMJ (Palomar and Doblaré, 2007).

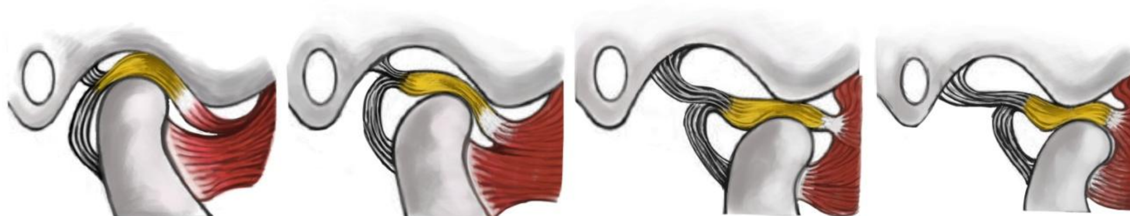


Image 2: Normal TMJ, disk adaptations during mouth opening.

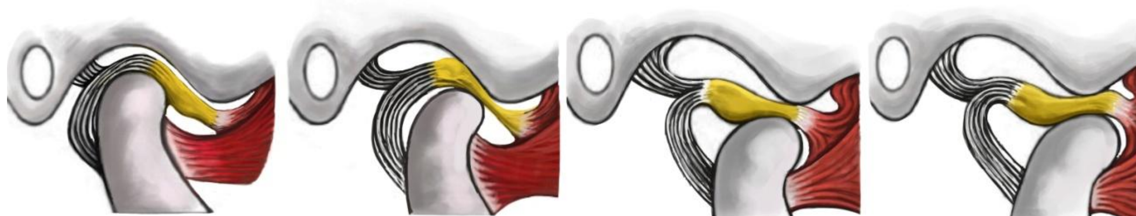


Image 3: TMJ disk displacement with reduction, disk adaptations during mouth opening.

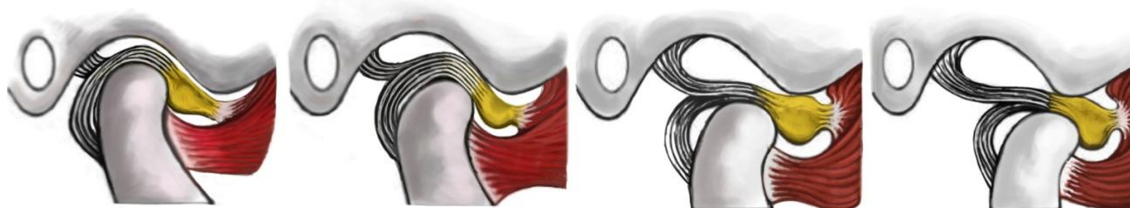


Image 4: TMJ disk displacement without reduction, disk adaptations during mouth opening.

A study of Timofiyeva and colleagues aimed to determine the condyle movement in healthy TMJ and in TMJ with disk displacement and joint sounds (click). The findings suggested that the asymptomatic joints have a characteristic pattern of movement (in the first degrees of jaw opening the condyle performs rotation and as the range increases, the condyle will be moving to forward of the fossa until the articular eminence). On the other hand, the symptomatic TMJ have shown a different pattern of movement (in the opening, the condyle almost does not perform the rotation movement, and in a advanced range of motion, the condyle seems to jump to a position of higher protrusion, reducing the joint space, when compared with the previous positions) (Tymofiyeva et al. 2007).

The TMJ joint sounds are common in symptomatic and asymptomatic populations, but this joint sounds probably reflects an abnormality in the structure and function of the joint (Prinz, 1998). Deng and colleagues study showed that the extent of joint sounds in subjects with disk displacement with reduction (10 TMJ evaluated) was significantly higher when compared to subjects with disk displacement without reduction (20 TMJ evaluated) as well as subjects without TMD (10 TMJ's evaluated) (Deng, Long, Dong, Chen and Li, 2006).

In the literature, two main guidelines for the diagnosis of disk displacement are found, viz., the Research Diagnostic Criteria for Temporomandibular Disorders (RDC/TMD) proposed by Dworkin and LeResche in 1992 and the Clinical Classification System of the American Academy of Orofacial Pain (AAOP). Patients with TMD should be classified according to widespread schemes such as RDC/TMD for epidemiological and research purposes and AAOP guidelines for classifications in clinical practice.

Table 1: Diagnostic Criteria for disk displacement according to the RDC/TMD (Dworkin e LeResche, 1992).

Diagnosis	Diagnostic Criteria RDC/TMD
Disk displacement with reduction	1. a) Reciprocal clicking in TMJ (click on both vertical opening and closing that occurs at a point at least 5mm greater interincisal distance on opening than on closing and is eliminated on protrusive opening, reproducible on two of three consecutive trials; or, b) click in TMJ on both vertical range of motion (either opening or closing), reproducible on two of three consecutive trials, and click during lateral excursion or protrusion, reproducible on two of three consecutive trials.
Disk displacement without reduction, with limited opening	1. History of significant limitation in opening; plus: 2. Maximum unassisted opening ≤ 35mm; plus: 3. Passive stretch increases opening by 4mm or less over maximum unassisted opening; plus: 4. Contralateral excursion < 7mm and/or uncorrected deviation to the ipsilateral side on opening, plus: 5. a) absence of joint sounds. Or, b) presence of joint sounds not meeting criteria for disk displacement with reduction.
Disk displacement without reduction, without limited opening	1. History of significant limitation of mandibular opening; plus: 2. Maximum unassisted opening > 35mm; plus: 3. Passive stretch increases opening by 5mm or more over maximum unassisted opening; plus: 4. Contralateral excursion ≥ 7mm; plus: 5. Presence of joint sounds not meeting criteria for disk displacement with reduction.

Table 2: Diagnostic criteria for disk displacement according to the AAOP.

Diagnosis	Diagnostic Criteria AAOP	Any of the Following May Accompany the Preceding Items
Disk displacement with reduction	1. Reproducible joint noise that occurs usually at variable positions during opening and closing mandibular movements. 2. Soft tissue imaging reveals displaced disk that improves its position during mandibular opening, and hard tissue imaging shows an absence of extensive degenerative bone changes.	• Pain, when present, is precipitated by joint movement; • Deviation during opening movement coincides with a click; • No restriction in mandibular movement; • Episodic and momentary catching during mouth opening (≤ 35mm) that self-reduces with voluntary mandibular repositioning.
Acute disk displacement without reduction	1. Persistent markedly limited mouth opening (≤ 35mm) with history of sudden onset. 2. Deflection to the affected side on mouth opening. 3. Markedly limited lateral excursion to the contralateral side (if unilateral disorder). 4. Soft tissue imaging reveals displaced disk without reduction.	• Pain precipitated by forced mouth opening; • History of clicking that ceases with locking; • Pain with palpation of the affected joint; • Ipsilateral hyperocclusion; • No or mild osteoarthritic changes with hard tissue imaging.
Chronic disk displacement without reduction	1. History of sudden onset of limited mouth opening. 2. Soft tissue imaging reveals displaced disk without reduction.	• Pain, when present, is markedly reduced from the acute stage; • History of clicking that resolved with sudden onset of the locking; • Crepitation on mandibular movement; • Gradual resolution of limited mouth opening; • Mild to moderate osteoarthritic changes with imaging of hard tissue.

2.3 The use of electronic devices in assessment of TMD

Several electronic devices, such as surface electromyography, kinesiographic records and posturography, have been described as reliable and accurate in assessment and evaluation of TMD, however its role is far to be consensual.

2.3.1 Surface Electromyography

The surface electromyography (sEMG) has been shown useful for assessing muscle function in research studies, being considered an important technique to assess global changes in the muscles, determining the patterns and strategies of muscle activation and coordination of different muscles that contribute to a specific movement (Pedroni, Borini and Bérzin, 2004).

Some authors proposed that quantitative methods as the sEMG may be used as a complement in the diagnosis of TMD and to monitorize the effectiveness of some treatments (Pedroni, Borini and Bérzin, 2004; Tartaglia et al. 2011; Widmalm, Lee and McKay, 2007; Cooper, 2011); however, it seems that much is yet to be done before defining the real specific indications of such devices.

Some studies claimed that sEMG may provide objective records of the function and dysfunction of the masticatory muscles, but it must be pointed out that most studies came from the research setting (Koyano, Kim and Clark, 1995; Castroflorio et al. 2005; Ferrario et al. 2007) and did not authorize the uncontrolled use of commercial sEMG in the clinical setting, as proposed by others (Widmalm, Lee and McKay, 2007). Electromyographic investigations performed in patients with TMD showed that the muscles of mastication may have altered firing features (Tosato and Caria, 2007; Koyano, Kim and Clark, 1995; Ardizone et al. 2010; Ferrario et al. 2007) and present higher silent periods (McCall, Uthman and Mohl, 1978) than subjects without TMD. In any case, the main sEMG finding associated with the presence of pain is the reduced activity during maximum clenching, in line with the pain adaptation model (Visser, McCarroll and Naeije, 1992, Manfredini et al. 2011).

The belief that the clinical applicability of surface EMG may be justified for the diagnosis and treatments of TMD is based on the assumption that the various pathological or dysfunctional conditions can be revealed by electromyographic records of muscle activity of the masticatory muscles. In any case, it must be borne in mind that current evidence-based concepts suggest that several biological factors (physiologic variation, age, sex, skeletal morphology, psychological factors, density of the skin, weight) and technical factors (position of the electrodes, position and interelectrode distance, cross-talk, head or body movements, existence of painful conditions, facial expressions, history of bruxism) may influence the reliability, validity, sensitivity and specificity of surface EMG as a diagnostic and treatment procedure (Klasser and Okeson, 2006).

Considering that, some systematic reviews suggests that the role of bioelectronic devices, in particular surface EMG, is less important than believed in the past, since they seem to be able, at best, to provide ancillary information (Lund, Widmer and Feine, 1995; Klasser and Okeson, 2006; Suvinen and Kemppainen, 2007; Manfredini et al. 2011).

The electromyographic activity of the masseter and temporalis muscles only presents acceptable sensitivity and specificity values for tasks that involves clenching, being able to distinguish patients with myofascial pain from non-patients during maximum clenching (Manfredini et al. 2011). On the contrary, the activity at rest and the difference in electromyographic activity between symmetrical muscles, have a poor accuracy in the distinction of patients to non-patients (Lund, Widmer and Feine, 1995;

Manfredini et al. 2011), featuring true-positive rates below 60% and false-positives between 44-89% (Manfredini et al. 2010).

Also at rest, comparisons of the painful side with the non-painful side on the same patient with unilateral facial pain showed that myoelectric activity levels did not differ significantly between the two sides evaluated. A clear and consistent relationship between the painful state of a muscle and its level of electric activity by surface EMG, has not been established yet (Baba et al. 2001).

In summary, the surface EMG seems to have some potential as a complementary tool in the investigation of the masticatory function (Suvinen and Kemppainen, 2007), but not as a tool for symptoms diagnosis (Lund, Widmer and Feine, 1995; Baba et al. 2001; Klasser and Okeson, 2006; Suvinen and Kemppainen, 2007; Manfredini et al. 2011).

2.3.2 Kinematic Analysis

The kinematic analysis it is a variation of kinesiographic recordings and describes the motion using linear (meters) or angular (degrees) measurements (Knudson, 2007). The most common methods to obtain kinematic data are high speed video systems that record the position of body segments with respect to time, typically using passive markers placed in the segments under consideration. Subsequently, the images are analyzed by specific software, some of free access such as Kinovea, using a reference system that allows collect coordinates in space (Hamill and Knutzen, 2009). Kinematic analysis of human movement through the aforementioned system is widely described in the literature (Decker et al. 2003; Wu et al. 2005; Medved, 2001), however, this analysis for active jaw movements was not found in related literature.

2.3.3 Posturography

The use of photographic techniques to analyze the body posture is widely described in literature (Santos, Silva, Sanada and Alves, 2009; Watson, 1998; Iunes et al. 2005; Cuccia and Carola, 2009; Burke et al. 2010; Ayub, Way and Kraus, 1984; Miranda et al. 2010; Raine and Twomey, 1994) and there are several studies that attempt to relate the body posture with TMD, by the use of balance platforms, generically known as posturography (Wakano et al. 2011; Chessa, Capobianco and Lai, 2002; Ferrario, Sforza, Schmitz and Taroni, 1996; Perinetti, 2007; Perinetti and Contardo, 2009; Manfredini, Castroflorio, Perinetti and Guarda-Nardini, 2012). As in the case of sEMG, also in the field of posturography, clinicians' beliefs about its potential usefulness in the clinical setting clash with findings from the research setting.

Posturography is a non-invasive technique, but the absence of significant relationships between body posture and TMD (Perinetti, 2007; Ferrario, Sforza, Schmitz and Taroni, 1996), makes the posturography little useful in the monitoring of body posture responses to changes in stomatognathic system (including TMD), with a high degree of imprecision due to the large variability of the records (Perinetti and Contardo, 2009).

Several studies using the posturography to establish a relationship between body posture and TMD, are focused on the correlation between the stomatognathic system and the cervical region, which cannot be representative of the global body posture (Perinetti and Contardo, 2009). Based on quantitative data obtained from two literature reviews, the several postugraphic devices and methods appears to be similar regarding to the high variability in records, resulting in low accuracy on clinical diagnosis (Perinetti and Contardo, 2009; Manfredini, Castroflorio, Perinetti and Guarda-Nardini, 2012).

2.4 Relationship Between Body Posture and TMD

The position of the head is an important center of balance for the body and its movements depends on the positioning and stability of the skull on the cervical region (Maciel, 2003). This region has the main function to maintain the centered position of the head on the spine and optimize their mobility (Sachse and Schildt-Rudloff, 2003).

A study of Tosato and colleagues indicates that women with cervicalgia showed more signs and symptoms of TMD when compared to a group of women with low back pain (Tosato et al. 2007).

Another study aiming to verify if the head posture affects the mandibular kinematics showed that different mandibular postures influence the intra-articular space of the TMJ and, therefore, the movement of the mandibular condyle. In the military posture of the head, the opening movement path of the incisal point is shifted anteriorly relative to its path in a natural head posture, whereas in a forward head posture this path is shifted posteriorly (Visscher, Slater, Lobbezoo and Naeije, 2000).

In the head there are two of the three mechanisms for posture control, viz., the oculomotor and the vestibular systems, which together with the function of the cervical spine determines the body position assumed by the subject. The TMJ is the link which shares neuromuscular structures between the jaw with the skull and cervical spine; when pain in the TMJ or jaw muscles is present it can trigger body postural changes (Wakano et al. 2011).

The neuroanatomical relationships of the cervical spine with the TMJ may induce changes in body posture because the afferent fibers of the trigeminal, hypoglossal, glossopharyngeal and vagus nerves converge to the trigeminal nucleus in the brainstem, with the efferent fibers of the first three cervical nerves (La Touche et al. 2011). The convergence of different types of ascending and descending fibers to the trigeminal nucleus, may contribute to pain and dysfunction of the cervical spine, temporomandibular joints and mastication muscles, due to changes in head posture (Coderre et al. 1993; Huggare and Raustia, 1992; Meyer, Kahn, Boutemy and Wilk 1998).

Relationship between agonist and antagonist muscles can contribute to postural changes (Marques, 2000). The hyperactivity of masticatory muscles (antagonist) interferes with the activity of the posterior muscular chain (agonist), causing changes on stretching-shortening relationship, which promotes exaggerated muscle tension that can lead to postural changes (Gagey and Weber, 2000).

One study suggests that in patients with TMD, postural changes and an abnormal muscle function are more common when compared to individuals without TMD, thus shows the influence of the cranio-mandibular system on body posture (Nikolakis et al. 2000).

Several studies have shown that the electromyographic activity of masticatory muscles can modify the electrical activity of postural muscles, especially the posterior cervical muscles (Lous, Sheik-Ol-Eslam and Moller, 1970; Ehrlich, Garlick and Ninio, 1999; Bergamini, Pierleoni, Gizdulich and Bergamini, 2008; Monaco, Spadaro, Cattaneo and Giannoni, 2010).

Many studies have attributed a relationship between TMD and posture, with the TMD of myofascial origin the most described, especially related to a Forward Head Posture (Ayub, Glasheen-Way and Kraus, 1984; Friedman and Weisberg, 1982; Janda, 1981; Goldstein, Kraus, Williams and Glasheen-Way, 1984; Urbanowicz, 1991; Gonzalez and Manns, 1996; Miranda et al. 2010).

Other studies indicate that postural changes such as unlevel shoulders (Clark, Green, Dorman and Flack, 1987; Fuents, Freesmeyer and Henriquez, 1999; Rocabado and Tapia, 1987), cervical lordosis increased (Clark, Green, Dorman and Flack, 1987; Darling, Kraus and Glasheen-Way, 1984; Munhoz, Marques and Siqueira, 2005; Neto et al. 2010) and rotation and/or head inclination (Farias, Alves and Gandelman, 2001), are also associated with TMD patients.

Another study shows that patients with intra-articular (internal derangement) TMD have postural deviations in the head, spine, shoulders, pelvis and hip joint. However, the major postural changes were found in structures adjacent to the TMJ. The body posture does not change randomly, but following a cranio-caudal standard. This suggest that the postural changes are a consequence of TMD and not the contrary (Munhoz and Marques, 2009).

Conversely, studies of Perinetti and Iunes, found that there were no significant postural changes in TMD patients (Perinetti, 2007; Iunes et al. 2009).

Likewise, a literature review performed by Manfredini and colleagues suggests that there no evidence to a measurable and repeatable relationship between occlusion and posture, and that the presence of TMD pain is not likely to be mainly related to occluso-postural abnormalities (Manfredini, Castroflorio, Perinetti and Guarda-Nardini, 2012). Thus, due to its complexity and involvement of many systems (stomatognathic, musculoskeletal, neuromuscular, oculomotor, vestibular, proprioceptive) with inherent

personality characteristics (psychosocial factors), a need for studies on the physiology of such relationship in the absence of pain symptoms is strongly recommended.

The controversy around this issue and the lack of studies that prove categorically the relationship between TMD and changes in body posture, leads us to conduct this study, where we hope to clarify this relationship.

3. Methodology

This research study represents a cross-sectional quasi-experimental design.

To perform the study, subjects from two institutions of higher education and from a temporomandibular rehabilitation clinic were evaluated. All subjects underwent physical evaluation of joint range of motion and joint noises during jaw opening and lateral excursions active movements according to the protocols described by Dworkin and Leresche (RDC/TMD) and the American Academy of Orofacial Pain (AAOP). The study took place at the facilities of Instituto Superior de Saúde do Alto Ave (days 11, 12 and 18 May 2012) and Escola Superior de Tecnologia da Saúde de Coimbra (days 24 and 25 May 2012).

All subjects in the study were properly informed about the procedures to be carried out and about the objectives of the study with their rights to privacy and confidentiality assured. Participants were also informed that they could withdraw at any time and that from the ongoing investigation does not result any consequences to their physical integrity. They were allowed to place any issue that was not properly clear and finally, it was asked the voluntarily signing of the informed consent according to the Helsinki Declaration.

For this study, subjects were selected according to the following criteria:
- Aged between 15 and 40 years;
- Presence of joint sounds during jaw movements reproducible in 2 of 3 repeated trials and/or history of joint sound currently evolved to blocking or marked limitation in range of mandibular movements **(Test Group)**.
- Absence of joint sounds during jaw movements and no limitation in range of mandibular movements **(Control Group)**.

Exclusion Criteria:
- Degenerative diseases such as osteoarthritis or osteoarthrosis;
- Systemic diseases such as rheumatoid arthritis, systemic lupus erythematosus or collagen disease;
- History of trauma to the neck and/or in facial region;
- History of changes in the balance (frequent falls) or pain symptoms influenced by orthostatic position;
- Orthopedic or dentistry surgery with impact on the mobility of the TMJ.

The sample, obtained by convenience, is composed by 42 subjects. The control group is consisted by 21 subjects without any symptoms in the TMJ, 15 are females and 6 are males with a mean age of 21.2 (±3.7) years, with a mean height of 169.3 (±7.7) centimeters [cm] and mean weight of 73.7 (±14.8) kilograms [kg]. The test group consists of 21 subjects with internal derangement of the TMJ, among whom 17 are

female and 4 are male, the mean age stands at 22.2 (±3.9) years, the mean height is 169.7 (±7.8) cm and mean weight is 70.2 (±14.6) kg.

3.1 Experimental Setup

The room was prepared according to the space required, taking into account the luminosity and the inside temperature. The placement of the referential (described later in section 3.2.4), constituted the reference for the placement of the remaining instruments, whose distance was measured from the plywood board. The NeuroCom ® platform was placed 0.28 meters [m] from the anterior part of the referential, laterally centered therewith, the center of the tripod supporting the camera Casio® EX-FH20 for kinematic analysis was at a distance of 2.76 m from the anterior part of the referential. The center of the tripod supporting the camera Sony® HX-100V for the postural analysis was 3.43 m from the posterior part of the referential, as illustrated in the image 5.

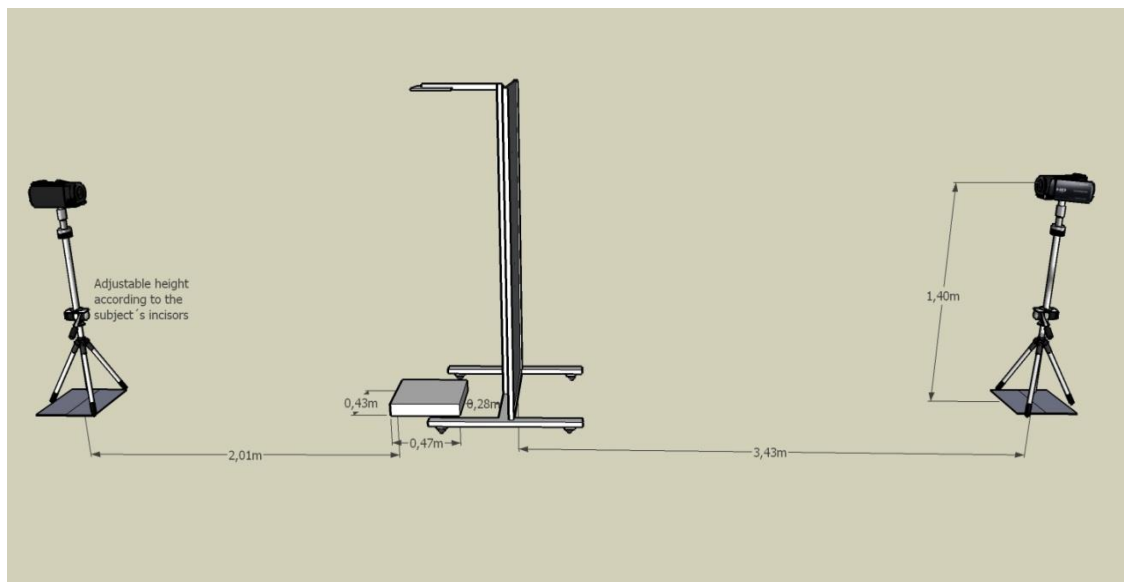


Image 5: Experimental setup scheme.

To perform the calibration of NeuroCom® platform standard weights of 11Kg were used. The data collection was made using the camera Casio® EX-FH20 at an acquisition rate of 30 Hertz [Hz], and with manual zoom of 20 millimeters [mm]. The photographic records were obtained through the camera Sony® HX-100V with flash on and without any zoom.

3.2 Instruments

3.2.1 Balance Platform

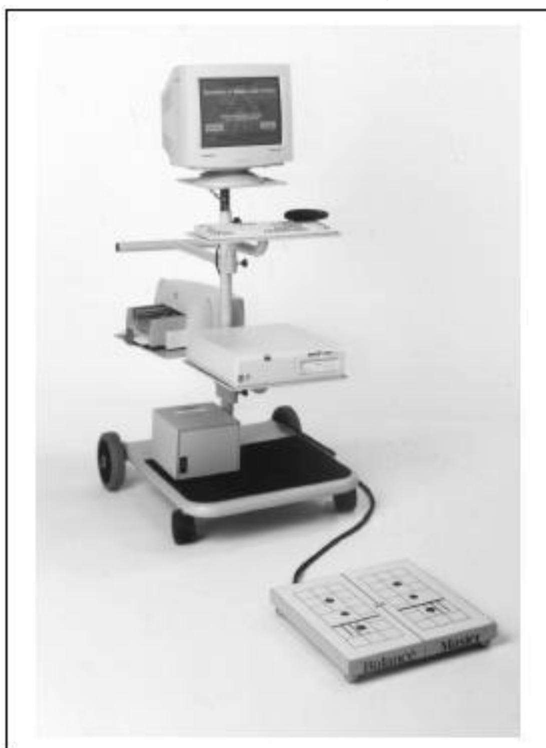


Image 6: Balance platform components.

Data from subjects balance was collected with the Basic Balance Master® platform from the company NeuroCom® International, Inc., headquartered in Clackamas, United States of America (USA).

This instrument consists of a force plate linked to a computer with the software provided by the manufacturer (Image 6). It was developed to support the assessment and treatment skills related to balance and mobility in patients with disabilities and/or functional limitations resulting from the orthopedic, neurological, geriatric or vestibular diagnostics (Basic Balance Master® System Operator's Manual, 2003).

The software used was the Clinical Test for the Sensory Interaction on Balance (CTSIB). Each test consists of three trials of 10 seconds each, in which are the initial alignment of the center of gravity (COG), the oscillation speed of the COG and the path of the COG.

In the first test three trials of opening-closing were performed, in the second test three trials of right lateral excursion and return to the midline while in the third test three trials of left lateral excursion and return to the midline. In the fourth test only one trial was done without any movement with the subject looking straight and focusing on a fixed point – it was done for comparison purposes only. The data which was taken into account was the speed of oscillation of the COG (degrees/second) [º/s] and the mean of displacement of the COG (degrees) [º]. All values were collected at an acquisition rate of 100 Hz.

The above mentioned equipment allows the study of the center of gravity which is considered the point of action of the total body weight, an imaginary point where the entire body mass is considered to be concentrated with respect to gravity. In normal subjects, in static upright posture, the COG in the transverse plane is located at S1-S2 and slightly forward of the ankle joints in the sagittal plane. The COG and the center of

mass (COM) are equivalent points in space where gravity is the only force taken into account (Basic Balance Master® System Operator's Manual, 2003).

Balance Master® platform measures the speed of oscillation of the COG as the ratio of distance traveled by COG (degrees) versus the time of repetition (seconds) indicating the amount of oscillation showed for the subject (Basic Balance Master ® System Operator's Manual, 2003). The ability to control the COG in the base of support in various external conditions (different surfaces, forces acting on the body, visual feedback, etc.), is the main function of balance, where low oscillation values indicates little movements of the body, meeting the preservation of this ability.

3.2.2 Surface EMG

Image 7: Surface EMG components.

The bioPLUXresearch® device from the company Plux – Engenharia de Biosensores, Ltd., based in Covilha, Portugal was used to collect the electromyographic signal. The software supplied by the manufacturer, enables collecting the electromyographic signal at a sampling rate of 1000 Hz (bioPLUXresearchUser Manual, 2010).

Ambu® Blue Sensor electrodes, reference N-00-S, from the company Ambu A/S based in Ballerup, Denmark are used. These sensors are silver/silver chloride with wet gel conduction system (http://www.ambu.com/corp/products/patient_monitoring_and_diagnostics.aspx/product.aspx?ProductID=PROD844, seen in 22/08/2012).

3.2.3 Digital Cameras

Two digital cameras were used, one for jaw movements video recording (kinematic analysis) and the other to the photographic records to perform the postural analysis. The camera used for the video recording was the Casio EX-FH20® from the company Casio Computer CO., LTD., Ltd. Tokyo, Japan. To make the photographic records was used the camera Sony® HX-100V, Sony Corporation, Tokyo, Japan. The tripods used were Hama® "Star 63", Hama Lda. Basingstoke, United Kingdom.

3.2.4 Referential

A referential was constructed to facilitate the analysis of the collected data (Image 8). Supporting structure was built of galvanized steel with a board of plywood in between, previously prepared with a grid chart for postural evaluation, scaled in centimeters. The basis of this structure was formed by two lateral bars with 1.0 m each and a central bar to connect the two lateral bars with 0.86 m. At the bottom of the two side bars, one wheel was placed at each end which raised the referential structure at the platform height (0.06 m) (Image 9). In the central part of the two side bars, leaving two vertical bars with 2.0 m where two rails fit through the plywood board. The central part of the central bar also leaves a vertical bar with previously prepared 2.0 m measuring tape. On the top of this bar, a height adjustable headrest was placed to provide proprioceptive information for subjects not to move the head upwards and sideways during mandibular motion (Image 10). As the purpose of this instrument was not restraining subjects' normal movement, it just landed on top of the hair, not making any pressure on the head (Image 11). This head support is built with a steel bar with 0.56 m which engages on the vertical bar and the flat part is constructed with a plywood board with 0.25 m long by 0.26 m wide and lined with a ethylene-propylene-diene rubber (EPDM). Passive markers were placed on the grid chart, translating specific measures in order to minimize the measurement errors in the analysis (Image 12).

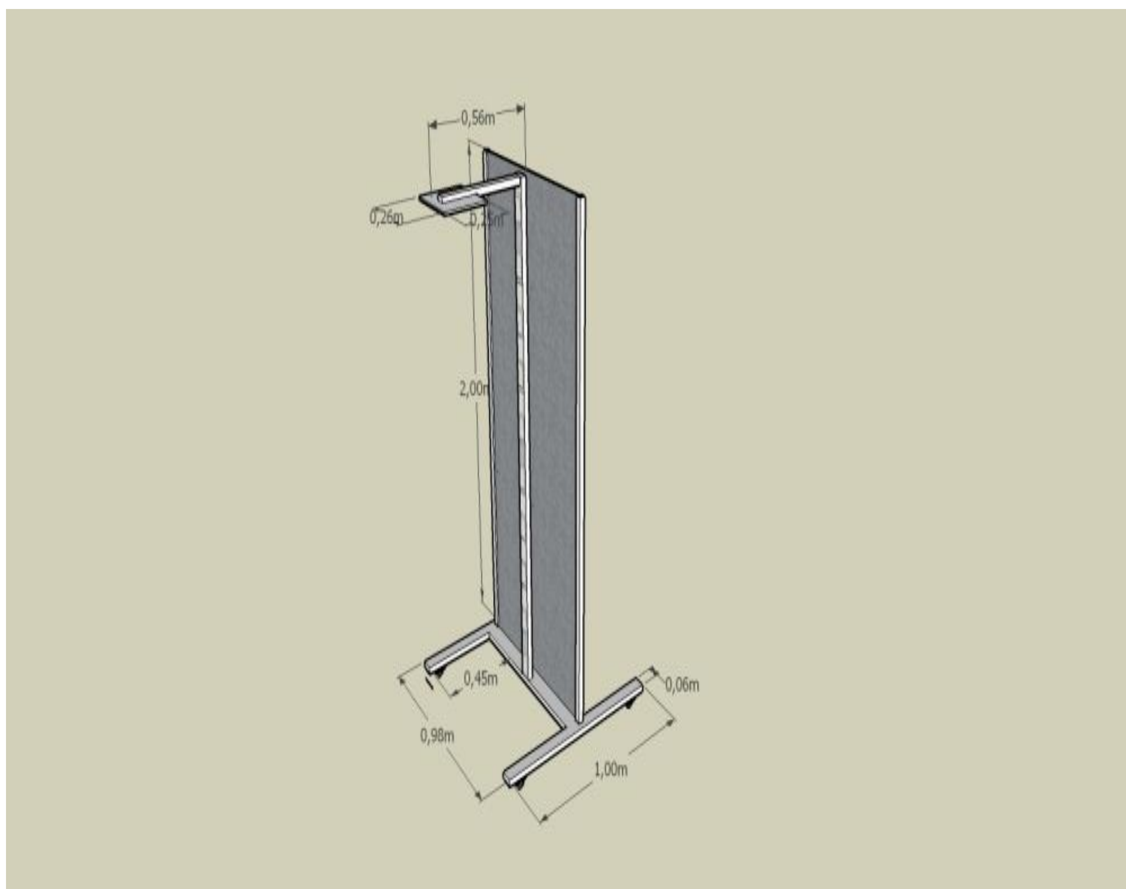


Image 8: Referential scheme.

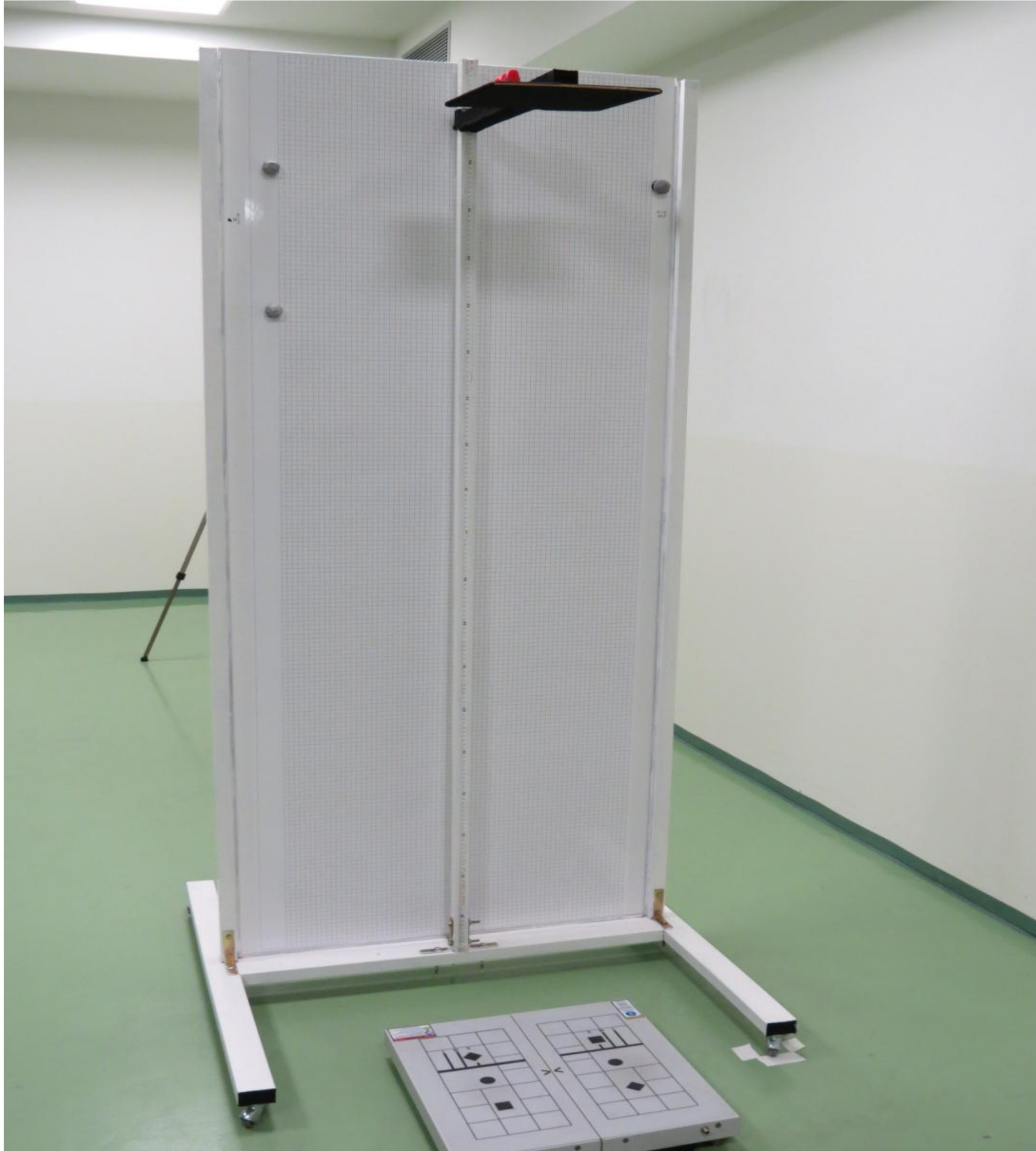


Image 9: Referential front.

Image 10: Referential headrest.

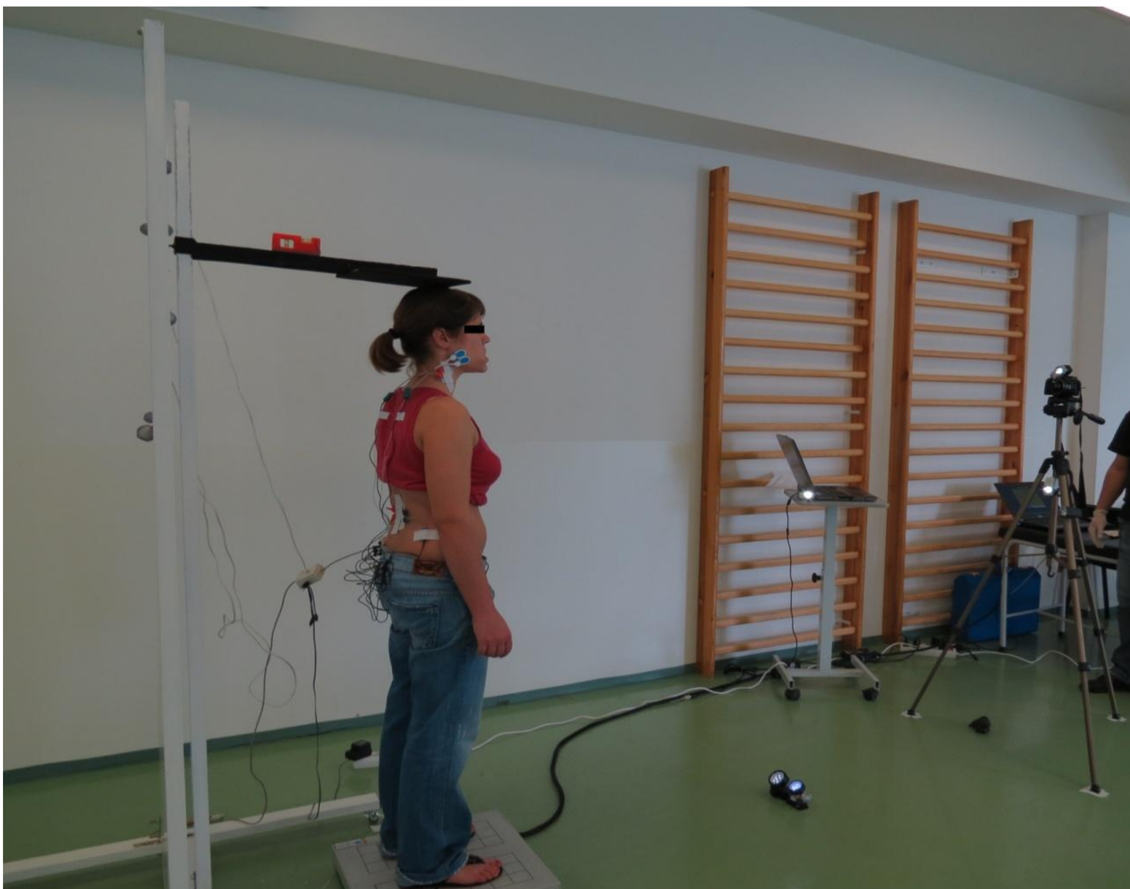


Image 11: Headrest function.

Image 12: Referential back.

3.3 Procedures

Procedures started by informing the subjects about the study, allowing them to clear any question and asking them permission to carry on with the study.

Then, some sample characterization questions were asked and height measurement was performed using the referential. In the test group the temporomandibular joints were also evaluated to define the diagnosis of disc displacement to the right, left or bilaterally.

Next step was skin preparation for placement of the electrodes surfaces (Ambu® Blue Sensor N-00-S) on the muscles used on the study. With this purpose, the skin on the muscles area was shaved if necessary, dead cells removed with Omnitape® adhesive from the company Hartmann, Heidenheim, Germany, and skin cleaning with alcohol soaked wipes from the company Romed®, Wilnis, Netherlands.

The electromyographic activity was collected of the masseter muscles (electrodes in an ideal line between the angle of the mandible and the pupil center, parallel to the long axis of the muscle), sternocleidomastoid muscles (electrodes at 3 cm below of the mastoid process, parallel to the long axis of the muscle) and spinae erectores muscles (electrodes bilaterally at 5cm to the spinous process of L4) according to the modified protocol proposed by Bergamini, Pierleoni, Gizdulish and Bergamini, 2008. In the placing of detection surfaces (electrodes) was used the protocol proposed by Konrad (The ABC of EMG). With the aim of increasing the visualization of the largest volume of the muscle belly, one voluntary contraction was asked before the placing the detection surfaces, which was performed on the location corresponding to the largest volume of muscle belly in rest position. Reference electrode was placed on

the sternum manubrium. The inter-electrode distance (center to center) was 2 cm and their placement had the following configuration:

Table 3: Electromyography configuration.

Order	Muscle	Channel
1º	Reference on the sternum manubrium	G
2º	Left Masseter	1
3º	Right Masseter	2
4º	Left Sternocleidomastoid	3
5º	Right Sternocleidomastoid	4
6º	Left Spinae Erector	5
7º	Right Spinae Erector	6
8º	Synchronization	7

Then electromyographic recording of the maximum voluntary contraction (MVC) of the muscles under evaluation for the purposes of normalization in intensity was made, and two followed contractions have been requested to the subject:

- **Masseters:** with the subject in a standing position, 2 dental cotton rolls from the brand Celluron® Hartmann, Heidenheim, Germany were placed in the region of the molars and premolars between the upper and lower dental arch (1 in the right side and 1 in the left side). The subject was asked to bite the rolls with maximum force for 3 seconds;

- **Sternocleidomastoid:** with the subject in the standing position and the evaluator also standing, looking forward to a left profile view of the subject, the right arm of the evaluator stabilizes the right shoulder of the subject, the subject is asked for a maximum contraction during 3 seconds in the position of cervical rotation to the right and inclination to the left, while the evaluator resists the movement with his left hand on the left temporal region of the volunteer. This process evaluates the left sternocleidomastoid muscle, and it was repeated for the right sternocleidomastoid muscle, reversing the evaluator and subject positions.

Image 13: Sternocleidomastoid MVC procedure.

- **Spinae Erectors:** with the subject in a standing position and the feet slightly apart from the couch, he was asked to lean the pelvis against the couch and then make a maximum contraction of extension movement of the trunk for 3 seconds with the evaluator behind the subject to carry out manual resistance in the scapular region.

Image 14: Spinae Erectors MVC procedure.

Passive roundness markers made of reflective material previously glued to parchment paper to improve the dental adherence (Image 15) were placed between the upper and lower central incisors, with 5 mm of diameter (Image 16). Dental cotton rolls were also placed for clearance of the lips and better visualization of the passive markers.

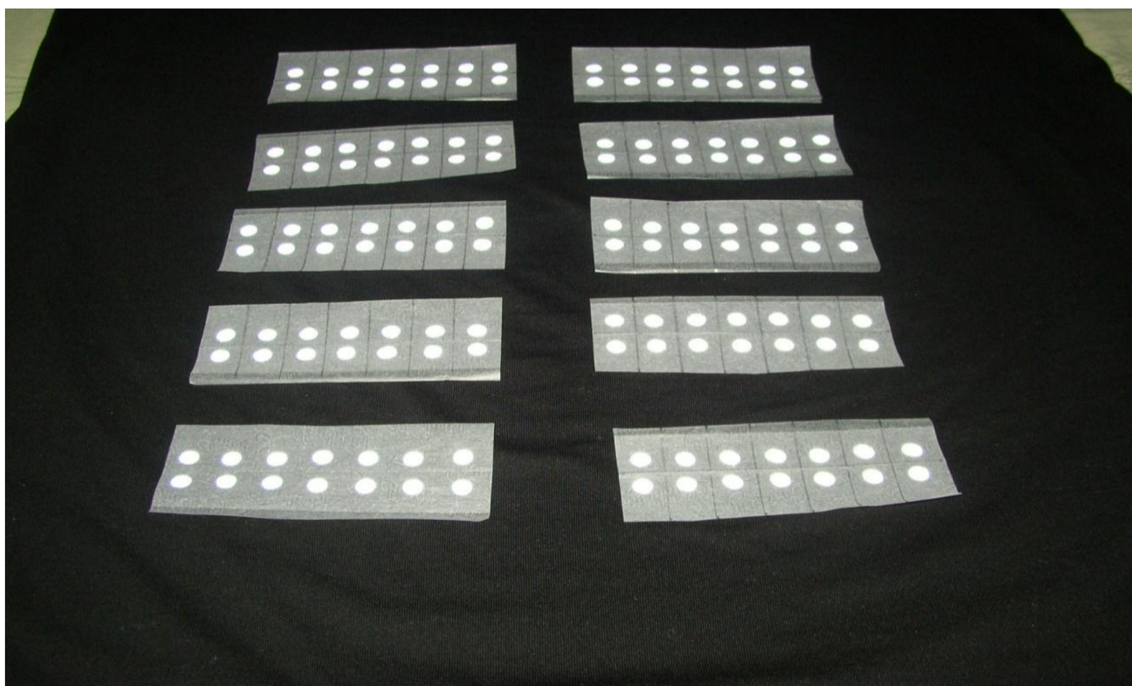


Image 15: Passive roundness markers.

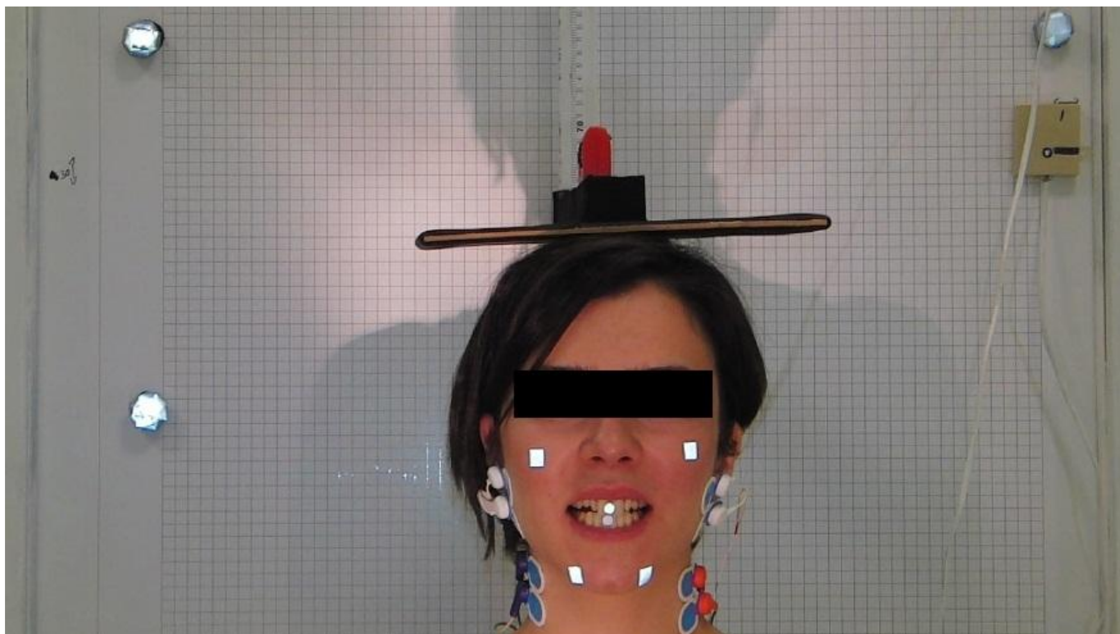


Image 16: Passive roundness markers placed in the subject.

The subjects were asked to put on top of the balance platform and the headrest was set to their height, just resting lightly on his head. The synchronization between instruments was performed by a switch that sends simultaneously a light signal captured on the video and an electrical signal (5V) recorded by the BioPlux device. Subjects were then requested to perform 3 maximum openings, 3 right excursions and 3 left excursions. During these movements the kinematics of the mandible, the path and the sway velocity of the COG and also the EMG were recorded.

At the end of this procedure, the passive markers and all the electromyographic apparatus were removed and skin was cleaned with alcohol soaked wipes to remove any gel from the removal of detection surfaces.

New passive reflective spherical markers were placed for postural analysis, on the tragus (bilaterally), on the midpoint between the angle of the mandible and the mandibular condyle (bilaterally), on the spinous process of the 7th cervical vertebra, on the acromion (bilaterally), on the antero-superior iliac spine (bilaterally), on the postero-superior iliac spine (bilaterally), on the greater trochanter (bilaterally), on the lateral femoral condyle in its lateral region (bilaterally), on the anterior tibial tuberosity (bilaterally) and on the lateral malleolus (bilaterally) (Image 17).

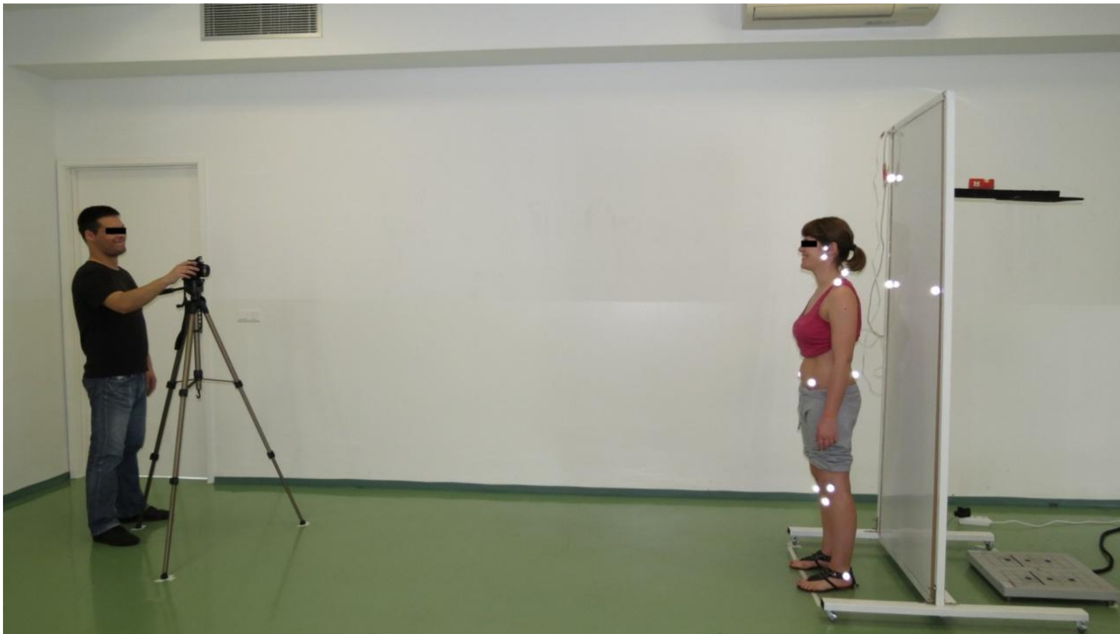


Image 17: Passive spheric markers placed in the subject.

Finally, 4 photographs were made for later postural analysis in anterior, posterior, lateral left and lateral right views.

3.4 Analysis Procedures

3.4.1 Kinematic Analysis

Kinematic analysis was performed using the Kinovea© software version 0.8.15.

For the motion recordings of jaw opening and lateral excursions, the passive markers of central incisors at the moment of maximum ROM of the joint for the different movements, were used (Image 18).

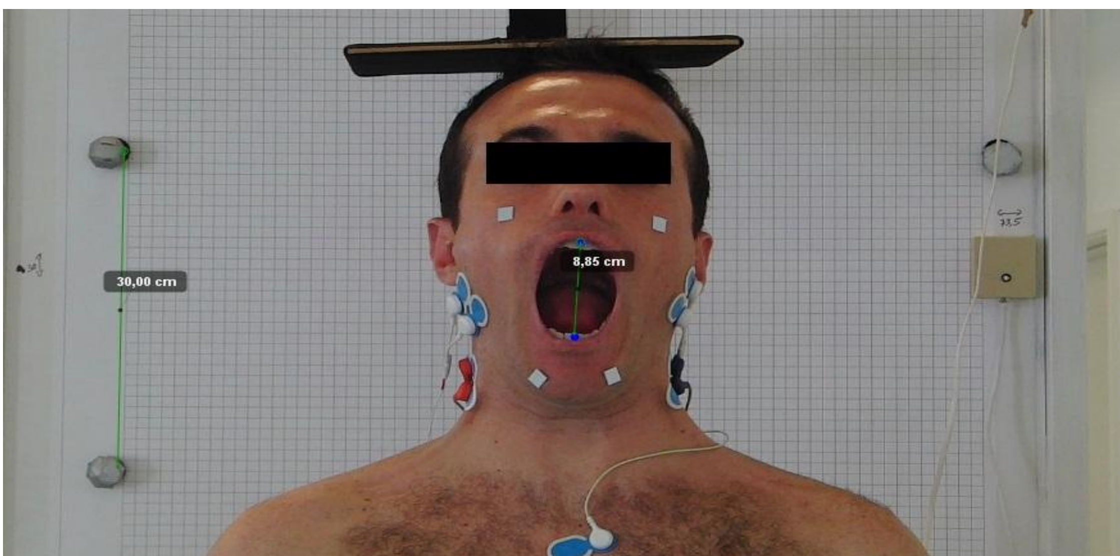


Image 18: Maximum ROM analysis.

The jaw horizontal displacement and vertical displacement were registered during the opening and closing movements using the lower passive marker (jaw central incisors), from the beginning of the opening movement to the moment of maximum opening (Image 19). For the jaw closing movement the same passive marker was used, from the time of maximum opening to the maximum mandibular closing.

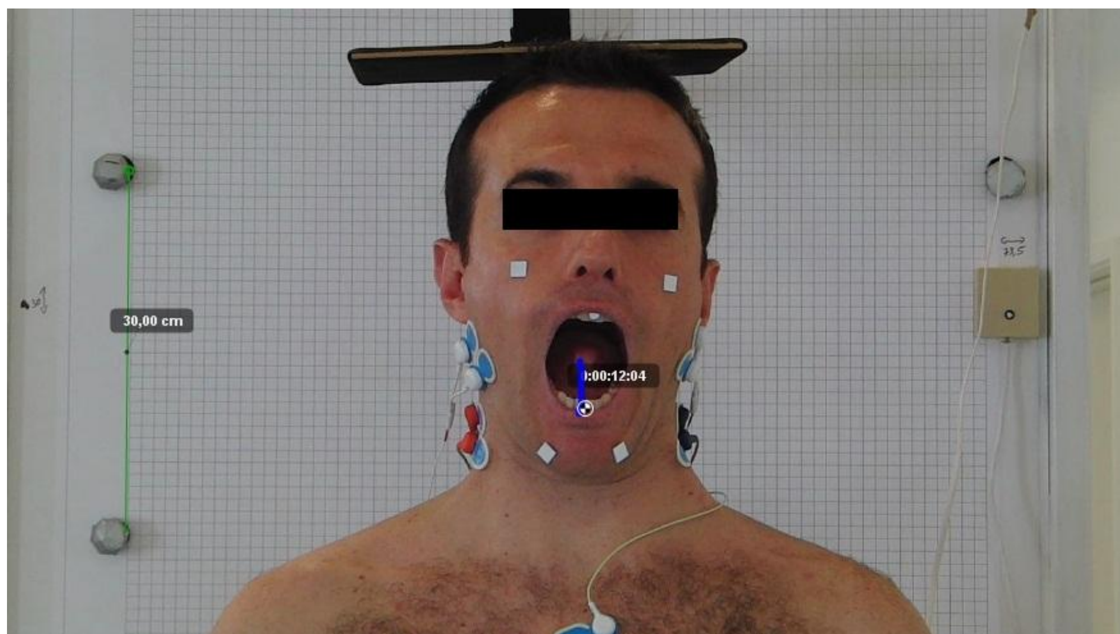


Image 19: Jaw displacement analysis.

This data was exported to Microsoft Excel, part of Microsoft Office Professional Plus 2010, Microsoft© Corporation.

Data analyzed during the three repetitions of opening and closing was gathered in the following format:

- Maximum X: maximum horizontal displacement in cm [(+) signal indicates displacement to the left side, and (-) signal indicates displacement to the right side];
- Maximum Y: maximum vertical displacement in cm [(+) signal indicates elevation/closing of the jaw, and (-) signal indicates depression/opening of the jaw];
- Moment of Maximum Lateral Deviation: indicates in which amplitude of the vertical displacement (initial, middle or final) occurs the maximum horizontal displacement, ie, the moment of opening and closing when the lateral deviation is maximum;
- Xfinal – Xinitial: indicates if the final position in the horizontal plane is different from the initial position (final opening vs. initial opening or final closing vs. initial closing);
- Total XY: obtained by junction coordinate formula $\sqrt{(x_2-x_1)^2 + (y_2-y_1)^2}$ to indicate the amount of jaw displacement.

3.4.2 Postural Analysis

Postural assessment was also performed with Kinovea© software.

Anterior and posterior views were used to check for an elevated segment of bilateral structures, tragus, acromions, antero-superior iliac spines, postero-superior iliac spines, greater trochanters, external femoral condyles, tibial tuberositys and external malleolus. The reference position, considered normal for these bilateral structures, was 180º, indicating the alignment in the frontal plane. The reference for evaluation was placed in the center of the right passive marker of the tragus, completing an angle of 90° at the time of placement. The vertical arm was adjusted to make an angle of 180° and after this configuration, it was considered the fixed arm. The movable arm was placed on the center of the passive marker in the contralateral structure (left tragus) and its value was recorded. This process was repeated for all bilateral structures mentioned above (Image 20).

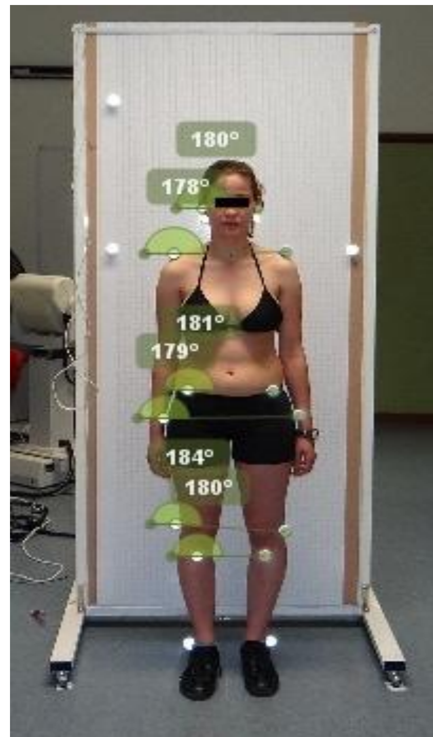


Image 20: Asymmetrical elevations analysis.

The anteriorization or posteriorization of the head was evaluated in right lateral view, placing the reference on the center of the C7 passive marker and forming a 90º angle. The horizontal arm was considered the fixed arm and the moving arm was placed on the center of the right tragus passive marker, the value obtained by this angle was registered.

The cervical flexion or extension was also evaluated in right lateral view placing the reference on the center of the tragus passive marker forming an angle of 90°. The vertical arm was adjusted to make an angle of 180° and after this arm configuration it was considered the fixed arm. The moving arm was aligned with the center of the eye socket and the obtained value was recorded (Image 21).

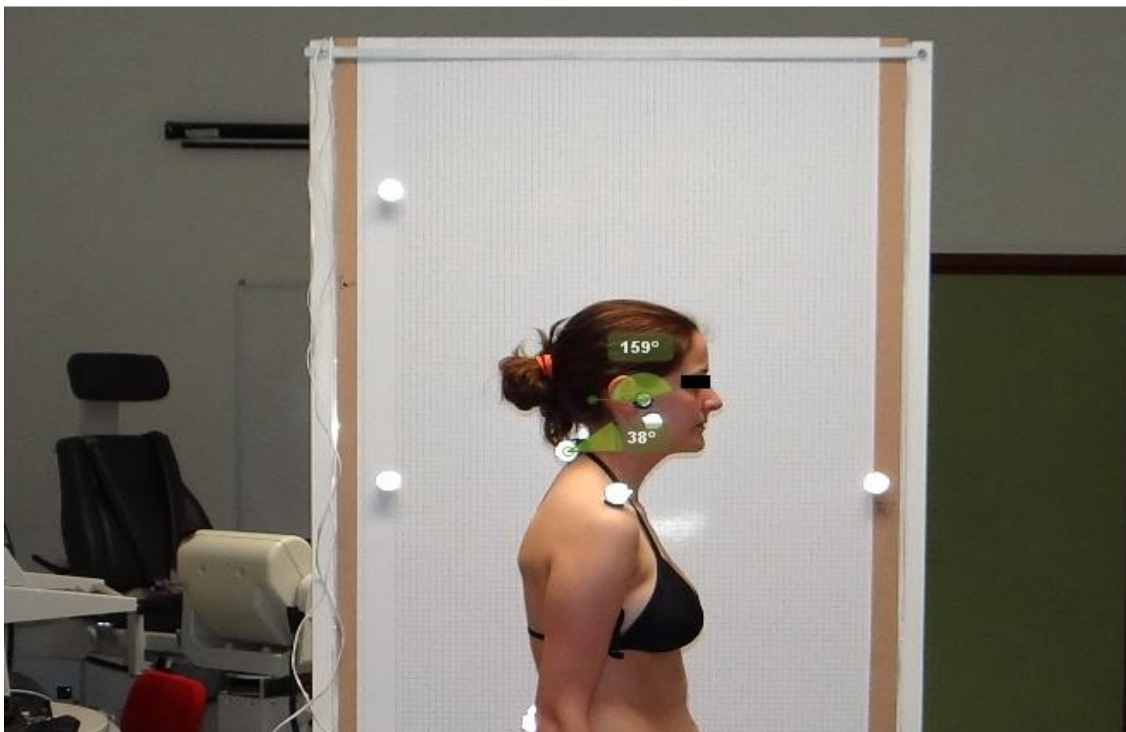


Image 21: Anteriorization of the head and flexion/extension of the head analysis.

The length of each segment evaluated in right lateral view was compared with the same segment's length in left lateral view. The reference length of passive markers on the board was 50 cm (Image 22).

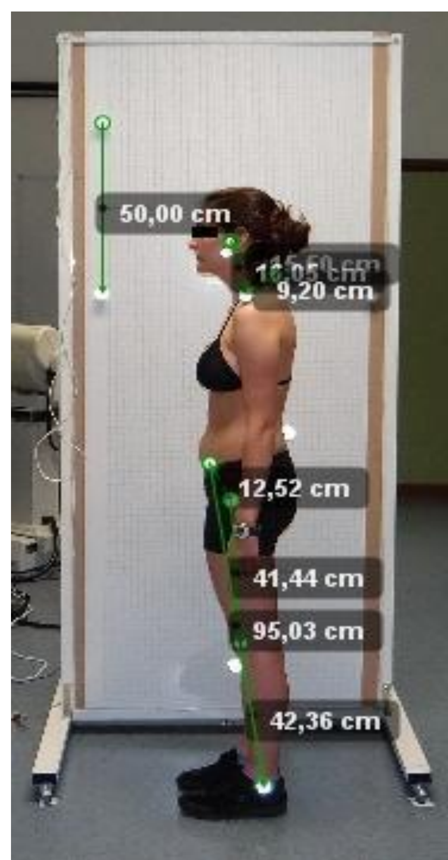


Image 22: Bilateral distances analysis.

A line was drawn between two passive markers of the evaluated segments and compared with the contra lateral segments. The segments used were the following:

- C7 - Tragus
- C7 - Acromion
- Acromion - Tragus
- Antero-superior Iliac Spine - Great Trochanter
- Great Trochanter - Lateral Femoral Condyle
- Lateral Femoral Condyle – Lateral Malleolus
- Antero-superior Iliac Spine – Lateral Malleolus.

The description of each parameter code is the follow:

Table 4: Posture parameters description.

Code	Evaluation	Plan	Description
Parameter 1	Anteriorization of the head #	Sagital	Tragus - C7; C7 - Horizontal plan (lower α, more anteriorization)
Parameter 2	Flexion/Extension of the head #	Sagital	Tragus - Eye socket (Normal 180º)
Parameter 3	Bilateral Distances (muscle shortening) right vs left	Sagital	C7 - Right tragus
Parameter 4		Sagital	C7 - Left tragus
Parameter 5	Inclinations of the head * #	Coronal Anterior	Right tragus - Left tragus
Parameter 6	Bilateral Distances (muscle shortening) right vs left	Sagital	Right acromion - Right tragus
Parameter 7		Sagital	Left acromion - Left tragus
Parameter 8	Asymmetrical Elevations *	Coronal Anterior	Acromions - Horizontal plan
Parameter 9		Coronal Anterior	Anterosuperior Iliac spines - Horizontal plan
Parameter 10		Coronal Anterior	Great Trochanters - Horizontal plan
Parameter 11		Coronal Anterior	Lateral femoral condyles - Horizontal plan
Parameter 12		Coronal Anterior	Tibial tuberositys - Horizontal plan
Parameter 13		Coronal Posterior	Posterosuperior Iliac spines - Horizontal plan
Parameter 14		Coronal Posterior	Lateral malleolus - Horizontal plan
Parameter 15	Dysmetrias	Sagital	Right Great Trochanter - Right Lateral femoral condyle
Parameter 16		Sagital	Right Lateral femoral condyle - Right Lateral malleolus
Parameter 17		Sagital	Left Great Trochanter - Left Lateral femoral condyle
Parameter 18		Sagital	Left Lateral femoral condyle - Left Lateral malleolus
Parameter 19	Bilateral Distances (muscle shortening) right vs left	Sagital	C7 - Right acromion
Parameter 20		Sagital	Right great trochanter - Right anterosuperior iliac spine
Parameter 21		Sagital	C7 - Left acromion
Parameter 22		Sagital	Left great trochanter - Left anterosuperior iliac spine
Parameter 23		Sagital	Right anterosuperior iliac spine - Right Lateral malleolus
Parameter 24		Sagital	Left anterosuperior iliac spine - Left Lateral malleolus

 # According with the altered protocol proposed by Raine and Twomey, 1994.

*** The correct alignment (180º) are represented as 0. The elevated segment are represented as (+) signal if it's elevated to the right side, and (-) signal if it's elevated to the left side.**

3.4.3 COG Sway Velocity and Path

The sway velocity of COG was obtained directly from the NeuroCom software provided by the manufacturer.

Image 23: NeuroCom software.

This data was post-processed in Microsoft Excel software. The average path of the COG was obtained by performing the average of "x" and "y" values of the 1000 entries made at each repetition. To this average was removed the first recorded value at each repetition which represents the position 0 of the COG. The values obtained by this process informs the average path of the COG during mandibular motion in the axis "x" (shift to the left[-]/right[+]) and the axis "y" (shift to anterior[+]/posterior[-]).

3.4.4 EMG Analysis

The raw EMG signal was imported to AcqKnowledge software, version 4.1 (BIOPAC Systems, Inc., England).

For the records relating to the MVC and jaw movements EMG, were applied 4 types of digital processing:

Raw EMG signals were collected at a rate of 1000 Hz. EMG signals were bandpass-filtered at 10-500 Hz, and full wave rectification followed by smoothing with and a low pass filter at 10 Hz 4th order (butterworth). The average mean in 100 miliseconds [ms] around the peak value was used to the study.

After this processing, the maximum values regarding the MVC for each muscle were analyzed, registering the value obtained in the highest contraction of the two evaluated.

For EMG related to mandibular movements, the periods corresponding to the 3 opening-closing movements, 3 right excursion-rest position movements and 3 left excursion-rest position movements, were identified. After this identification through time scale, the maximum values were recorded from each muscle in each of the movements mentioned above.

Later, within Microsoft Excel, these values of the jaw movements were normalized to the MVC values of the corresponding muscle, giving to these results a percentage of activation.

3.5 Statistics

It was used the program IBM® SPSS® Statistics, Version 20 for database construction and also for data structuring, transformation and interpretation.

We started the data analysis, performing a descriptive analysis of the study variables. Then was performed an analysis of repeatability of measurements (ANOVA univariate).

After was checked the assumptions of the variables normality (Kolgomorov-Smirnov test) and homogeneity of the variance between compared groups (Levene test), applying the parametric T-test Student if normality was checked (Pestana and Gageiro, 2000). Not verifying the previous assumptions, it was necessary the use of non-parametric tests for independent samples, in this case was used the Mann-Whitney test when significant differences was found for two independent samples.

For all tests was assumed a confidence level of 95%.

4. Results

The results will be presented in 7 parts, schematically divided in sample characterization, measurements repeatability, kinematic analysis, posture analysis, COG sway velocity and path analysis, EMG analysis and maximum ROM and vertical displacement.

4.1 Sample Characterization

Table 5: Male and female sample distribution on control and test groups.

Group	Male (N)	Female (N)	Total (N)	Male Percent (%)	Female Percent (%)	Valid Percent (%)
Control	6	15	21	28.6	71.4	100.0
Test	4	17	21	19.0	81.0	100.0
Total	10	32	42	23.8	76.2	100.0

The control group have 6 males (28.6%) and 15 females (71.4%) and the test group have 4 males (19.0%) and 17 females (81.0%). The total sample is composed by 10 males (23.8%) and 32 females (76.2%).

Table 6: Age, height and weight sample characterization measurements.

Group		N	Minimum	Maximum	Mean	Std. Deviation
Control	**Age (years)**	21	18	29	21.19	3.669
	Height (cm)	21	156	181	169.29	7.656
	Weight (kg)	21	45	98	73.67	14.769
Test	**Age (years)**	21	18	29	22.24	3.910
	Height (cm)	21	156	182	169.67	7.793
	Weight (kg)	21	48	113	70.19	14.566

The control group has a mean age of 21.2 (±3.7) years, with a mean height of 169.3 (±7.7) cm and a mean weight of 73.7 (±14.8) kg.

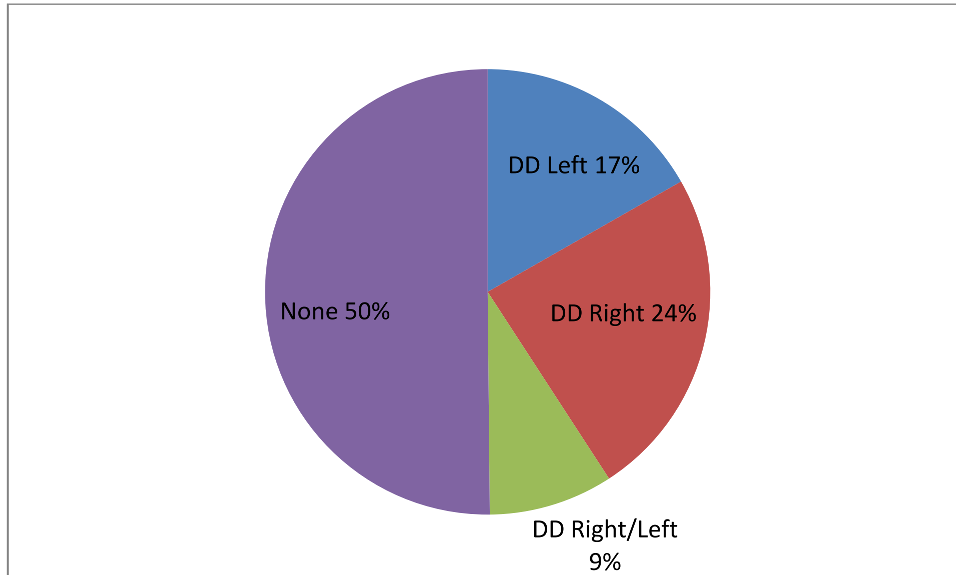
The test group has a mean age of 22.2 (±3.9) years, the mean height is 169.7 (±7.8) cm and the mean weight is 70.2 (±14.6) kg.

Table 7: Disk displacement diagnostic distribution.

Diagnostic	N	Male Frequency	Female Frequency	Valid Percent (%)
DD Left	7	1	6	16.7
DD Right	10	1	9	23.8
DD Right/Left	4	2	2	9.5
None	21	6	15	50.0
Total	42	10	32	100.0

The disk displacement (DD) diagnostic in the test group is distributed for 7 subjects with DD in the left TMJ (1 male and 6 females), 10 subjects with DD in the right TMJ (1 male and 9 females), and 4 subjects with DD in both sides of the TMJ (2 males and 2 females).

The control group doesn't have any diagnosis in the TMJ.



Graph 1: Disk displacement diagnostic percentage.

The percentage for DD in the left TMJ is 17%, for DD in the right TMJ is 24% and for DD in both sides of the TMJ is 9%.

4.2 Measurements Repeatability

In order to check the repeatability of the measurements, we first perform a statistical analysis of all variables composed by 3 repetitions.

Table 8: Study variables measurements repeatability.

ANOVA Univariate		
Variables	Control Group (Sig.)	Test Group (Sig.)
Maximum Opening	0.626	0.738
Maximum Right Excursion	0.811	0.801
Maximum Left Excursion	0.961	0.723
Max. X in Opening	0.974	0.294
Max. Y in Opening	0.086	0.097
Moment Max. Lat. Dev. in Opening	0.536	0.054
Xfinal-Xinitial in Opening	0.727	0.417
Total XY in Opening	0.221	***0.011***
Max. X in Closing	0.887	0.558
Max. Y in Closing	0.984	0.663
Moment Max. Lat. Dev. in Closing	0.513	0.532
Xfinal-Xinitial in Closing	0.862	0.308
Total XY in Closing	0.891	0.921
COG Sway Velocity Opening-Closing	0.951	0.876
COG Sway Velocity Right Exc.-Rest Pos.	0.147	0.929
COG Sway Velocity Left Exc.-Rest Pos.	0.862	0.512
COG Mean Path Opening-Closing X	0.210	0.168
COG Mean Path Opening-Closing Y	0.908	0.406
COG Mean Path Right Exc.-Rest Pos. X	0.406	0.551
COG Mean Path Right Exc.-Rest Pos. Y	0.859	0.178
COG Mean Path Left Exc.-Rest Pos. X	0.197	0.919
COG Mean Path Left Exc.-Rest Pos. Y	0.591	0.601
Open-Close Left Masseter	0.480	0.992
Open-Close Right Masseter	0.806	0.951
Open-Close Left ECM	0.874	0.845
Open-Close Right ECM	0.645	0.562
Open-Close Left Spinae Erec.	0.985	0.851
Open-Close Right Spinae Erec.	0.995	0.983
Right Excur-Rest Pos. Left Masseter	0.786	0.643
Right Excur-Rest Pos. Right Masseter	0.985	0.683
Right Excur-Rest Pos. Left ECM	0.856	0.943
Right Excur-Rest Pos. Right ECM	0.775	0.848
Right Excur-Rest Pos. Left Spinae Erec.	0.933	0.987
Right Excur-Rest Pos. Right Spinae Erec.	0.966	0.998
Left Excur-Rest Pos. Left Masseter	0.690	0.951
Left Excur-Rest Pos. Right Masseter	0.686	0.755
Left Excur-Rest Pos. Left ECM	0.975	0.770
Left Excur-Rest Pos. Right ECM	0.887	0.746
Left Excur-Rest Pos. Left Spinae Erec.	0.997	0.974
Left Excur-Rest Pos. Right Spinae Erec.	0.998	0.996

In both groups, all variables with exception of Total XY in Opening in test group (0.011), shows significance levels >0.05, which demonstrates that the 3 repetitions exhibit similar values. These results demonstrate that there is good repeatability of the measurements, giving some reliability to the study.

4.3. Kinematic Analysis

Table 9: Mean and statistical significance of the active ROM analysis.

Active ROM (mm)	Group	N*	Minimum	Maximum	Mean (±Std. Deviation)	Sig. (p value)
Maximum Opening	**Control**	62	51.3	79.5	62.0 (±6.7)	***0.039 #***
	Test	59	46.9	88.4	65.7 (±10.1)	
Maximum Right Excursion	**Control**	62	6.4	18.1	13.8 (±2.3)	0.489 **
	Test	59	8.5	20.4	14.1 (±2.7)	
Maximum Left Excursion	**Control**	61	4.4	20.5	13.9 (±4.1)	0.072 **
	Test	61	9.3	18.8	15.0 (±2.3)	

*** Valid/Completed repetitions in the 3 attempts.**
**** T-Test Student for independent samples. Significant differences: $p \leq 0.05$ at bold and italic.**
 # Mann-Whitney Test for independent samples. Significant differences: $p \leq 0.05$ at bold and italic.

The T-test for independent samples was performed to test the null hypothesis that no differences exist between the DD patients and the control subjects in the continuous outcome variables. It showed no between-group differences as for maximum right excursion (p=0.489) and maximum left excursion (p=0.072), ensuring the null hypothesis (h0= no differences between groups).

For maximum opening the equality of variances shows differences between groups (p=0.039), rejecting the null hypothesis.

In summary, by these results, we can say that subjects with DD did not differ from subjects without DD in respect to active ROM in the excursion movements. In the maximum opening movements, subjects with DD shows higher ROM (65.7 ±10.1 mm) than subjects without DD (62.0 ±6.7 mm).

Table 10: Mean and statistical significance of the jaw path analysis.

Jaw Path (cm)	Group	N*	Minimum	Maximum	Mean (±Std. Deviation)	Sig. (p value)
Max. X in Opening	**Control**	63	-0.9	2.0	0.1 (±0.6)	0.089 **
	Test	62	-1.1	0.9	-0.1 (±0.5)	
Max. Y in Opening	**Control**	63	-1.8	-5.4	-3.4 (±0.8)	0.272 **
	Test	62	-1.6	-4.9	-3.5 (±0.8)	
Moment Max. Lat. Dev. in Opening	**Control**	63	-0.3	-5.4	-3.0 (±1.0)	0.700 **
	Test	62	-0.2	-4.7	-3.0 (±1.1)	
Xfinal-Xinitial in Opening	**Control**	63	-0.9	1.96	0.1 (±0.5)	0.098 **
	Test	62	-1.0	0.9	0.0 (±0.4)	
Total XY in Opening	**Control**	63	1.9	5.8	4.0 (±0.8)	0.675 **
	Test	62	1.8	5.3	4.0 (±0.8)	
Max. X in Closing	**Control**	63	-1.3	0.9	-0.1 (±0.5)	***0.012 #***
	Test	62	-2.3	2.1	0.2 (±0.8)	
Max. Y in Closing	**Control**	63	1.3	6.1	4.1 (±1.0)	0.071 **
	Test	62	2.5	6.8	4.4 (±0.9)	
Moment Max. Lat. Dev. in Closing	**Control**	63	0.4	5.8	3.3 (±1.3)	0.792 **
	Test	62	0.1	6.2	3.4 (±1.4)	
Xfinal-Xinitial in Closing	**Control**	63	-1.3	0.7	-0.1 (±0.5)	***0.005 #***
	Test	62	-1.4	2.1	0.2 (±0.6)	
Total XY in Closing	**Control**	63	1.5	6.3	4.5 (±0.9)	***0.020 #***
	Test	62	3.5	7.7	4.9 (±0.8)	

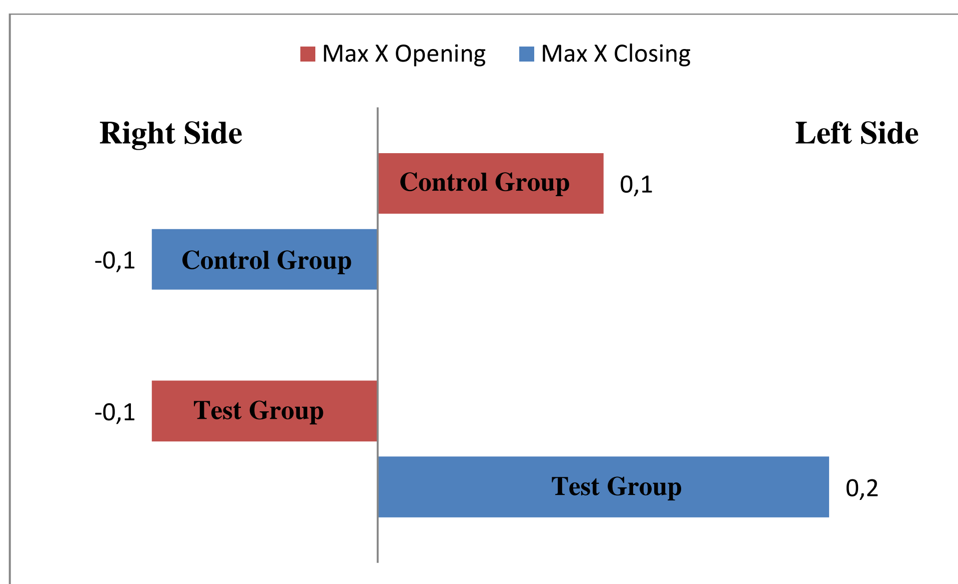
*** Valid/Completed repetitions in the 3 attempts.**
**** T-Test Student for independent samples. Significant differences: $p \leq 0.05$ at bold and italic.**
 # Mann-Whitney Test for independent samples. Significant differences: $p \leq 0.05$ at bold and italic.

The null hypothesis was confirmed for maximum X in opening (p=0.089), maximum Y in opening (p=0.272), moment of maximum lateral deviation in opening (p=0.700), Xfinal-Xinitial in opening (p=0.098), total XY in opening (p=0.675), maximum Y in closing (p=0.071) and moment of maximum lateral deviation in closing (p=0.792).

For maximum X in closing (p=0.012), Xfinal-Xinitial in closing (p=0.005) and total XY in closing (p=0.020), the null hypothesis was rejected, showing significant differences between groups.

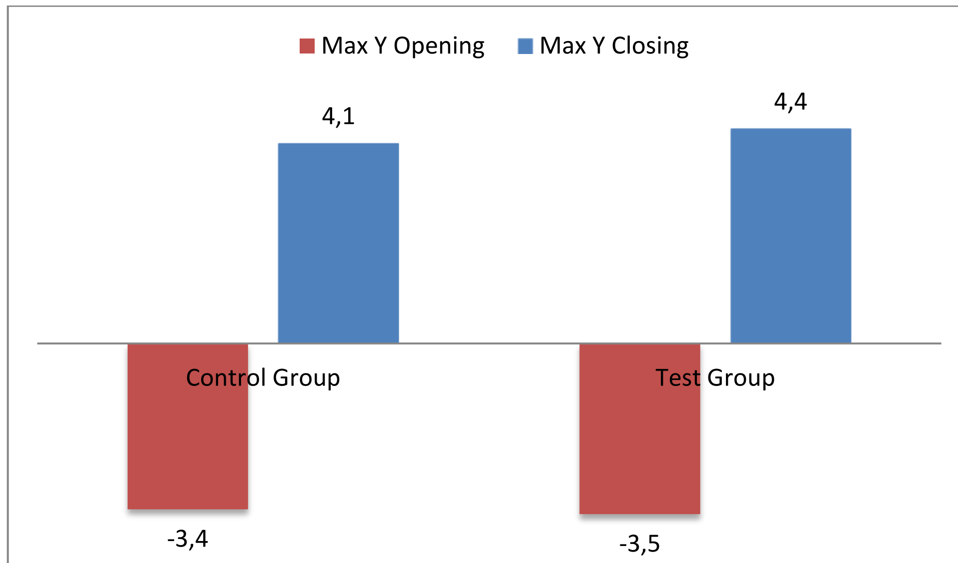
In synthesis, analyzing the jaw path in opening movements, we can say that subjects with DD did not show significant differences from subjects without DD. The mandibular path during closing movements has shown some differences between groups, with maximum horizontal displacement, final position different from initial position and amount of jaw displacement, showing higher values in subjects with DD.

To analyze the jaw vertical and horizontal displacement during opening and closing movements, a comparative analysis between groups it will be done.



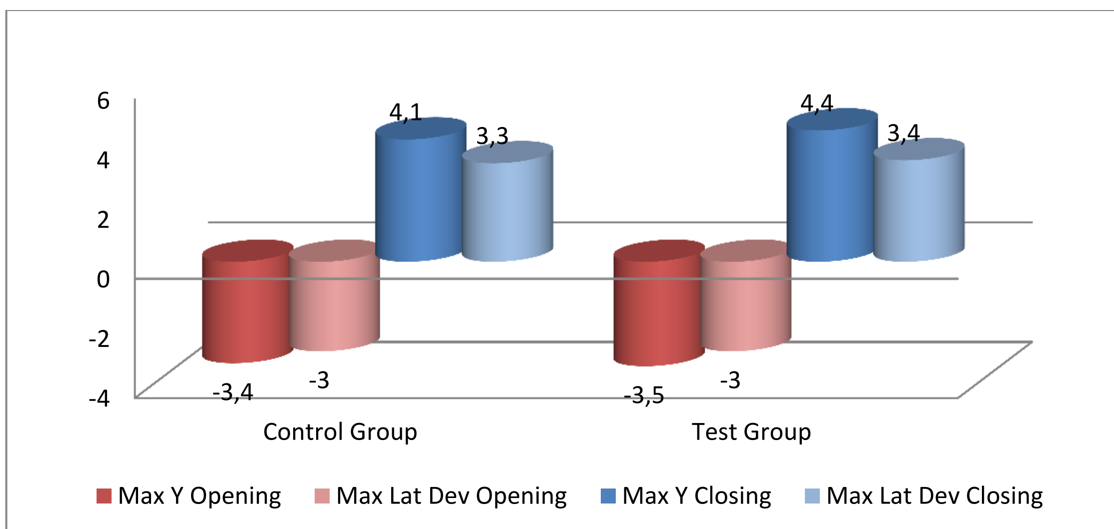
Graph 2: Horizontal jaw displacement (cm).

In opening movements both groups show the same maximal horizontal jaw displacement (0.1 cm), the only difference is that in non-DD group the horizontal displacement is to the left side and in the DD group is to the right side. In closing movements the horizontal displacement in non-DD group is 0.1 cm to the right side, equaling the start position. In the DD group the horizontal displacement is 0.2 cm to the left side, showing a little more horizontal displacement during closing movements.



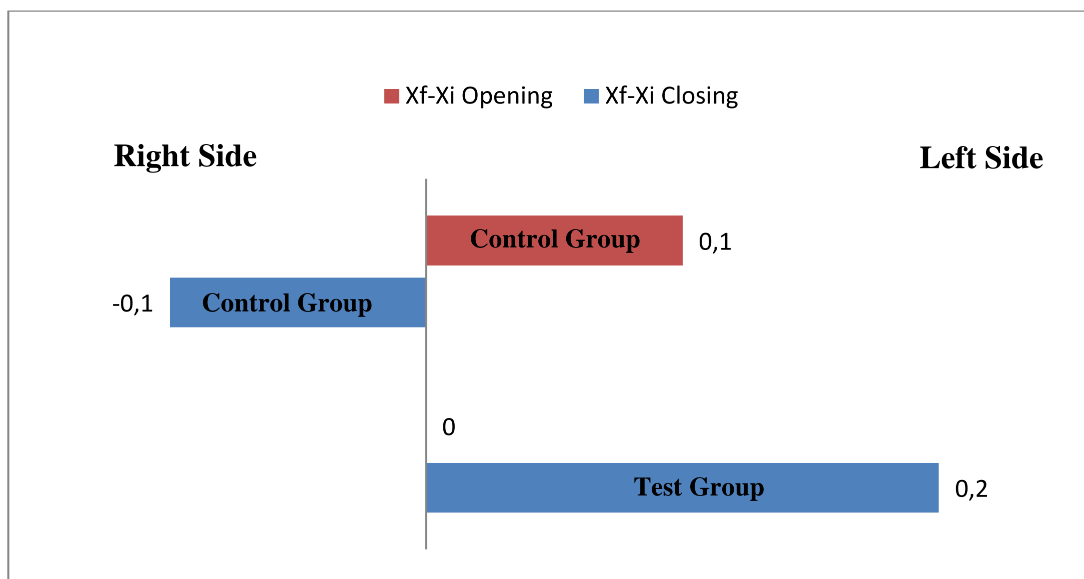
Graph 3: Vertical jaw displacement (cm).

In the vertical jaw displacement, both groups have higher values on closing movements when compared to the values obtained in opening movements, which means more movement during jaw closing. These results show that the non-DD group makes more 0.7 cm and the DD group more 0.9 cm in the closing movements than in the opening movements.



Graph 4: Moment of maximum jaw displacement (cm).

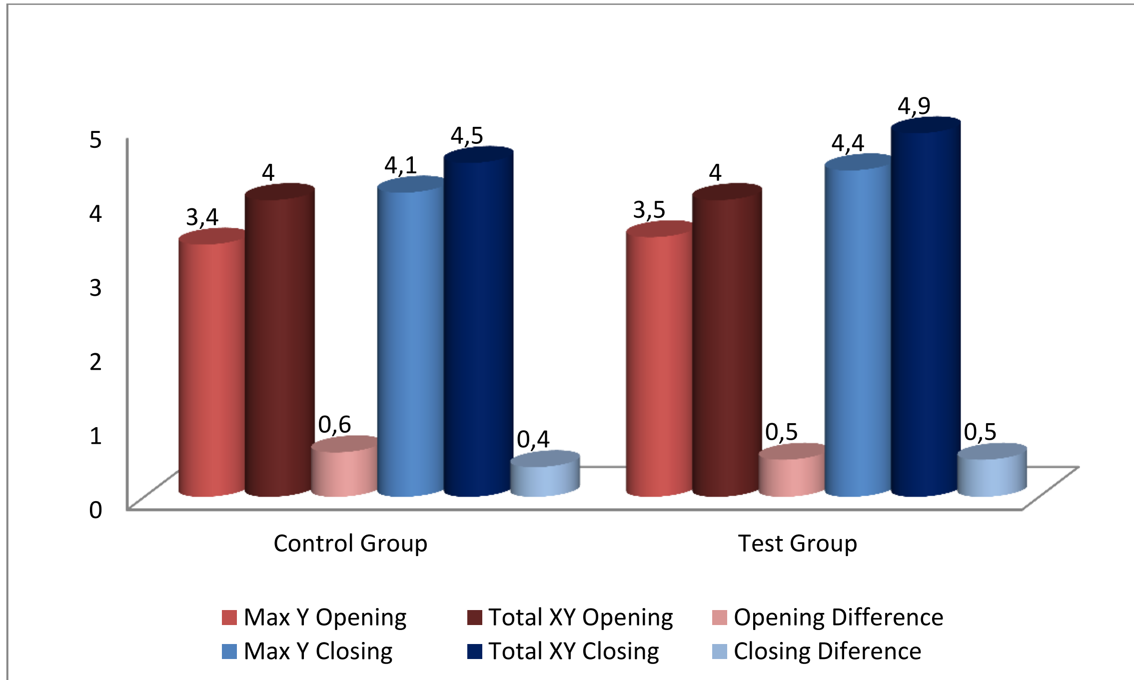
In both groups the maximum horizontal displacement occurs in the last third of movement also for jaw opening and closing, which translates more horizontal displacement near the end of opening and closing movements.



Graph 5: Horizontal jaw displacement difference from the end to the start point (cm).

In the opening movements, the end position of the jaw in the non-DD group differs 0.1 cm to the left side from the initial position, while the DD group doesn't show any changes between the final to the initial positions.

For the closing movements, the non-DD group shows that the final position differs 0.1 cm to the right side from the initial position, recapturing the horizontal alignment 0 (mouth closed). The DD group shows a final position 0.2 cm different from the initial position, and also from the horizontal alignment 0.



Graph 6: Total of vertical and horizontal jaw displacement (cm).

The total amount of jaw displacement in non-DD group is 4.0 cm for opening movements and 4.5 cm for closing movements, in which the horizontal displacement is 0.6 cm during opening and 0.4 cm during closing movements. In DD group, the total amount of jaw displacement is 4.0 cm and 4.9 cm for opening and closing movements respectively, in which the horizontal displacement is the same (0.5 cm) for the opening and closing movements.

These results show that the non-DD group (0.6) has a slightly higher horizontal displacement in opening movements then the DD group (0.5), and for the closing movements is the opposite, 0.5 in DD group and 0,4 in non-DD group.

In both groups, if we join the opening to the closing movements, we can verify that the total amount of horizontal displacement is the same (1.0 cm), not noticing any difference between groups.

4.4 Postural Analysis

Table 11: Mean and statistical significance of the posture segments analysis.

Posture Segments	Group	N*	Minimum	Maximum	Mean (±Std. Deviation)	Sig. (p value)
Parameter 1 (º)	**Control**	21	31.0	51.0	40.5 (±6.0)	0.077 **
	Test	21	36.0	53.0	43.6 (±4.8)	
Parameter 2 (º)	**Control**	21	150.0	180.0	162.9 (±8.0)	0.851 **
	Test	21	156.0	172.0	163.3 (±4.5)	
Parameter 3 (cm)	**Control**	21	13.7	21.5	16.7 (±1.8)	0.545 **
	Test	21	14.5	19.9	17.0 (±1.5)	
Parameter 4 (cm)	**Control**	21	14.5	23.7	17.0 (±2.1)	0.431 **
	Test	21	15.4	19.4	17.4 (±1.3)	
Parameter 5 (º)	**Control**	21	-5.0	3.0	-1.5 (±2.2)	0.122 **
	Test	21	-5.0	13.0	0.0 (±3.7)	
Parameter 6 (cm)	**Control**	21	12.6	20.8	18.0 (±2.1)	0.369 **
	Test	21	14.3	21.5	17.5 (±1.9)	
Parameter 7 (cm)	**Control**	21	14.5	19.8	17.4 (±1.5)	0.517 **
	Test	21	12.8	20.0	17.1 (±1.8)	
Parameter 8 (º)	**Control**	21	-5.0	2.0	-1.8 (±1.8)	0.277 **
	Test	21	-5.0	3.0	-1.1 (±2.1)	
Parameter 9 (º)	**Control**	21	-4.0	2.0	-0.2 (±1.7)	0.830 **
	Test	21	-5.0	6.0	-0.1 (±2.5)	
Parameter 10 (º)	**Control**	21	-5.0	4.0	-0.8 (±2.5)	0.408 **
	Test	21	-5.0	4.0	-0.1 (±2.3)	
Parameter 11 (º)	**Control**	21	-2.0	5.0	0.9 (±1.8)	0.740 **
	Test	21	-4.0	6.0	1.1 (±2.7)	
Parameter 12 (º)	**Control**	21	-9.0	4.0	-0.6 (±3.4)	0.553 **
	Test	21	-6.0	3.0	0.0 (±2.1)	
Parameter 13 (º)	**Control**	21	-10.0	4.0	-0.8 (±3.1)	0.872 **
	Test	21	-4.0	4.0	-0.6 (±2.6)	
Parameter 14 (º)	**Control**	21	-5.0	0.0	-2.3 (±1.5)	***0.004*** **
	Test	21	-3.0	5.0	-0.6 (±1.8)	
Parameter 15 (cm)	**Control**	21	33.6	48.2	40.5 (±4.9)	0.802 **
	Test	21	32.8	48.9	40.8 (±4.0)	
Parameter 16 (cm)	**Control**	21	39.7	48.8	45.1 (±2.7)	0.801 **
	Test	21	41.7	50.6	45.3 (±2.8)	
Parameter 17 (cm)	**Control**	21	35.1	48.9	41.9 (±4.2)	0.987 **
	Test	21	35.6	51.3	41.9 (±4.0)	
Parameter 18 (cm)	**Control**	21	38.3	51.5	44.9 (±2.9)	0.379 **
	Test	21	39.4	53.0	45.9 (±4.1)	
Parameter 19 (cm)	**Control**	21	6.4	14.7	11.0 (±2.3)	0.064 **
	Test	21	4.5	16.5	9.3 (±3.3)	
Parameter 20 (cm)	**Control**	21	13.0	20.3	16.2 (±2.3)	0.911 **
	Test	21	12.8	22.2	16.2 (±2.1)	
Parameter 21 (cm)	**Control**	21	7.7	15.2	10.5 (±2.0)	0.225 **
	Test	21	4.6	13.9	9.7 (±2.4)	
Parameter 22 (cm)	**Control**	21	11.5	20.5	15.1 (±2.2)	0.190 **
	Test	21	11.0	21.0	16.2 (±2.8)	
Parameter 23 (cm)	**Control**	21	87.0	112.4	99.8 (±6.5)	0.630 **
	Test	21	89.0	113.3	100.7 (±5.9)	
Parameter 24 (cm)	**Control**	21	87.4	114.5	100.6 (±6.8)	0.370 **
	Test	21	89.9	116.3	102.6 (±7.4)	

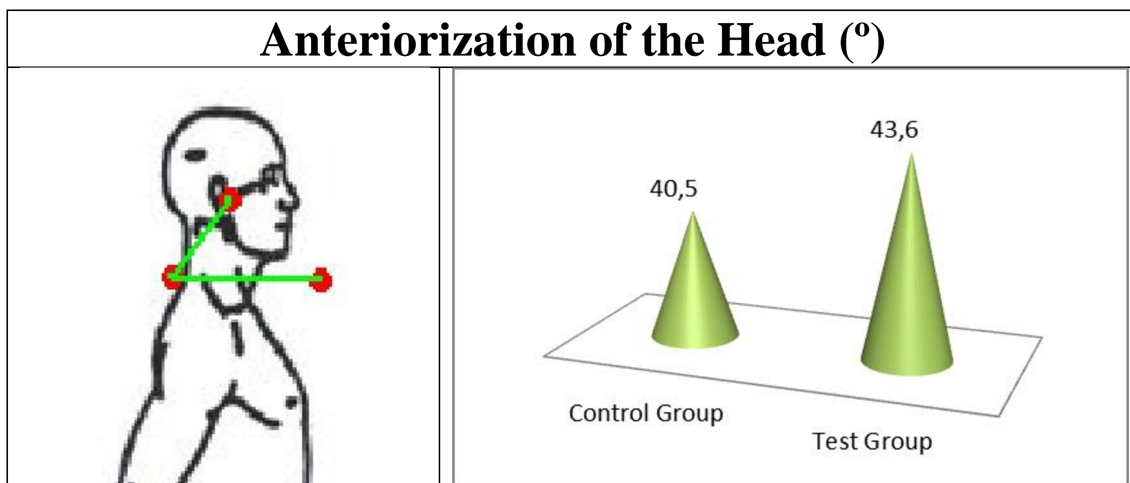
*** Valid/Completed repetitions in the 3 attempts.**
**** T-Test Student for independent samples. Significant differences: p ≤ 0.05 at bold and italic.**
 # Mann-Whitney Test for independent samples. Significant differences: p ≤ 0.05 at bold and italic.

With exception of parameter 14 (p=0.004), all other posture segments don't show significant differences between groups.

This parameter, representing an asymmetric elevation of the lateral malleolis shows high mean values in subjects without DD (-2.3 ±1.5) when compared to subjects with DD (-0.6 ±1.8).

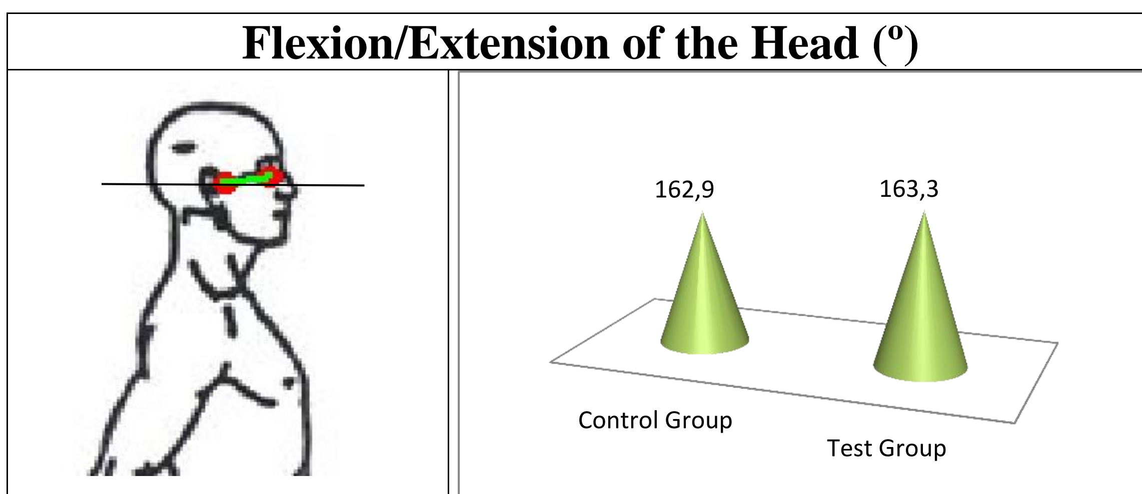
4.4.1 Posture Parameters:

In order to facilitate the data interpretation between groups and make comparisons between the right hemibody with the left hemibody, the postural parameters will be analyzed with graphs help.



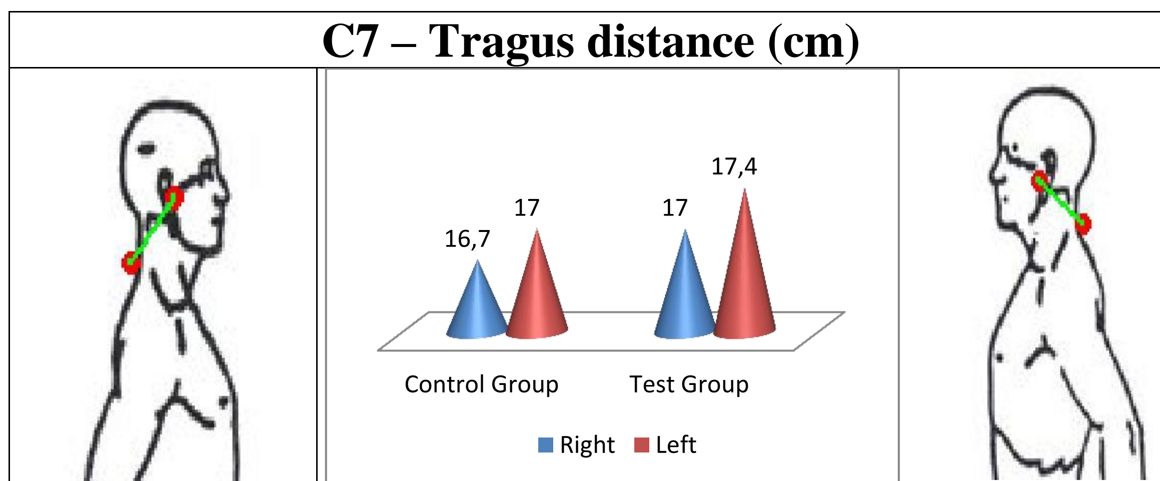
Graph 7: Posture parameter 1.

Both groups shows anteriorization of the head, but the lowest values are found in the without DD group, indicating that this group although slightly, has a more forward head posture than the DD group.



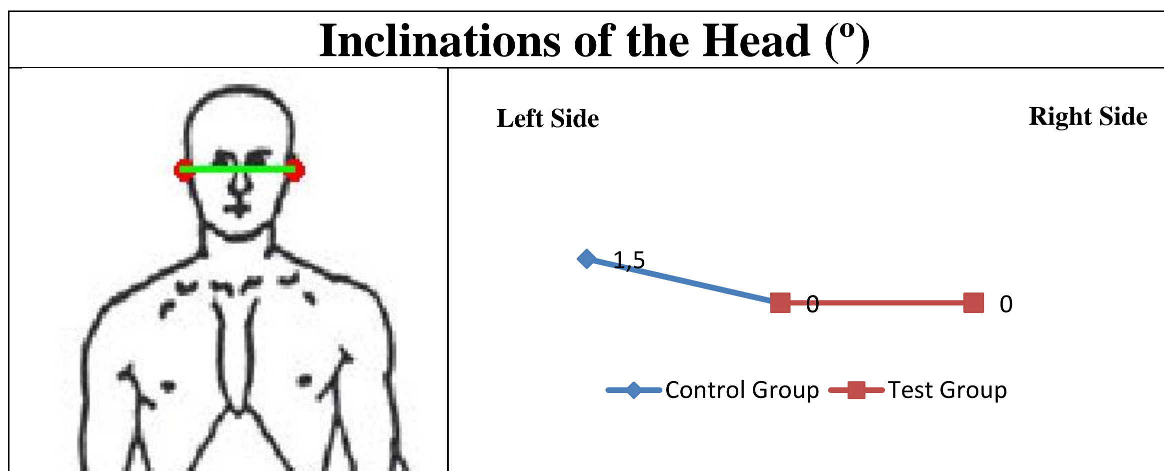
Graph 8: Posture parameter 2.

Both groups show an extension posture of the head, almost no differences were found between groups.



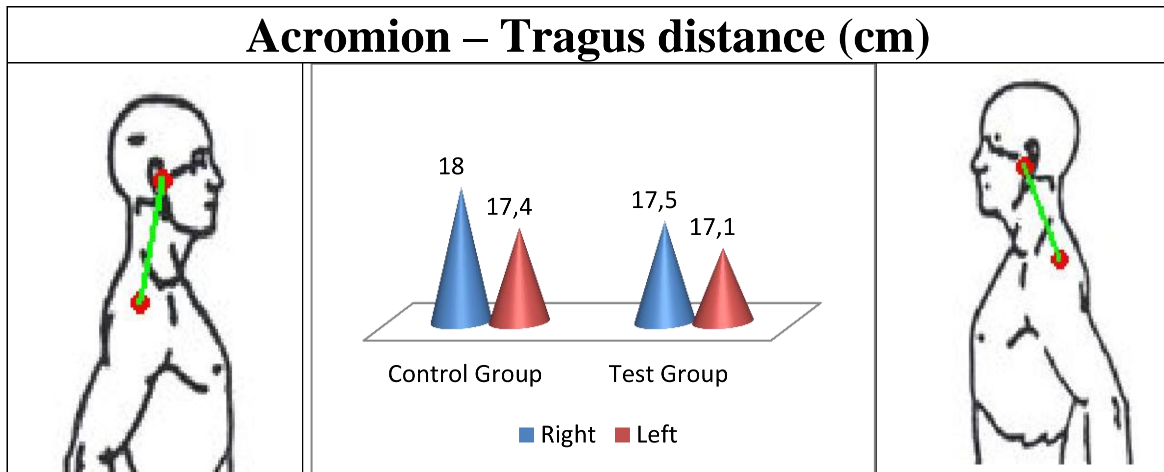
Graph 9: Posture parameters 3 and 4.

The bilateral distances between C7 and tragus are almost the same in both groups. The non-DD group shows 0.3 cm of head rotation to the right side, while the DD group shows 0.4 cm also to the right side.



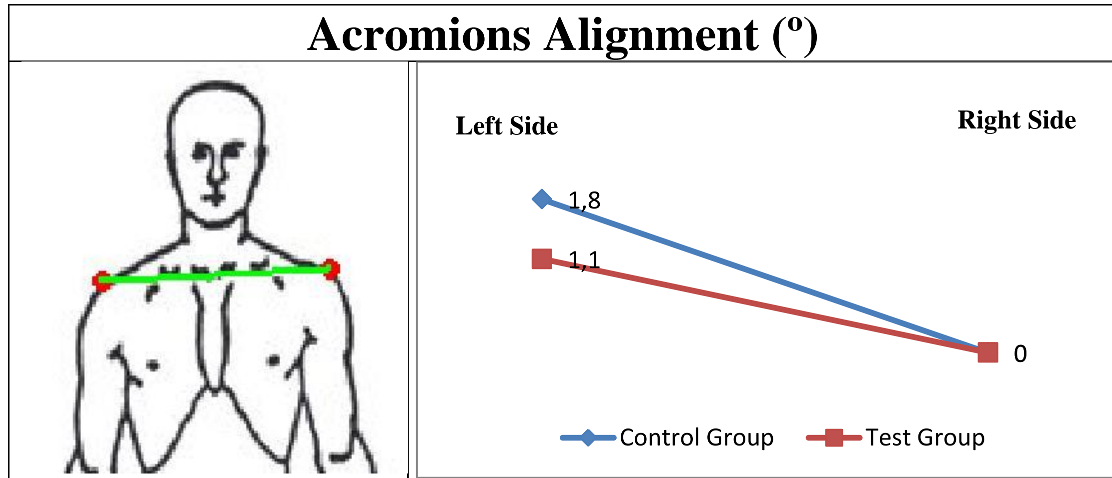
Graph 10: Posture parameter 5.

The non-DD group shows a difference between tragus alignment, 1.5º higher in the left side, which represents an inclination of the head to the right side. The DD group shows a correct alignment between right and left tragus.



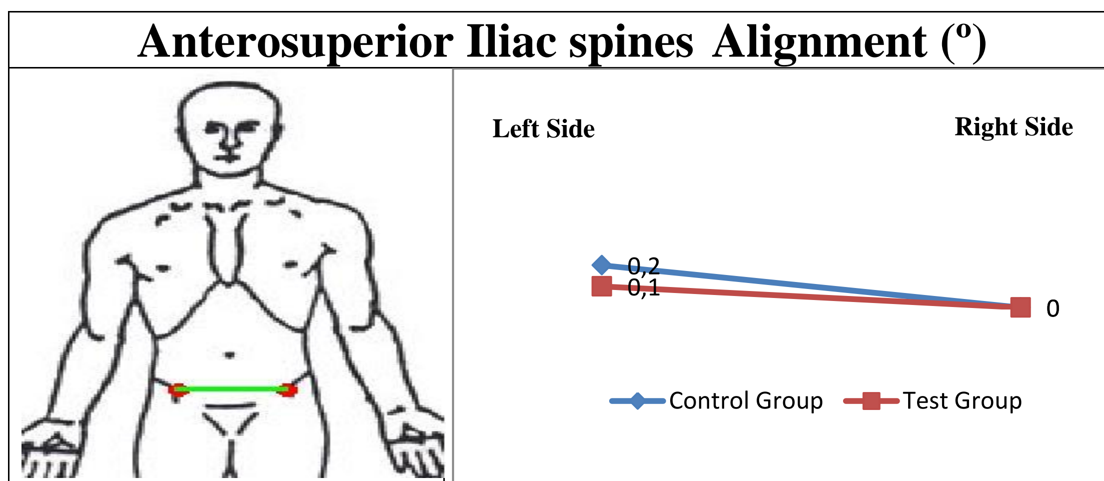
Graph 11: Posture parameters 6 and 7.

The bilateral distances between acromion and tragus differs 0.5 and 0.3 cm between groups, belonging the higher values to the non-DD group. In non-DD group the distance between these structures is lesser 0.6 cm in the left side, and in DD group lesser 0,4 cm also in the left side, indicating a muscle shortening in the left side in both groups, but this differences are not significant in any group.



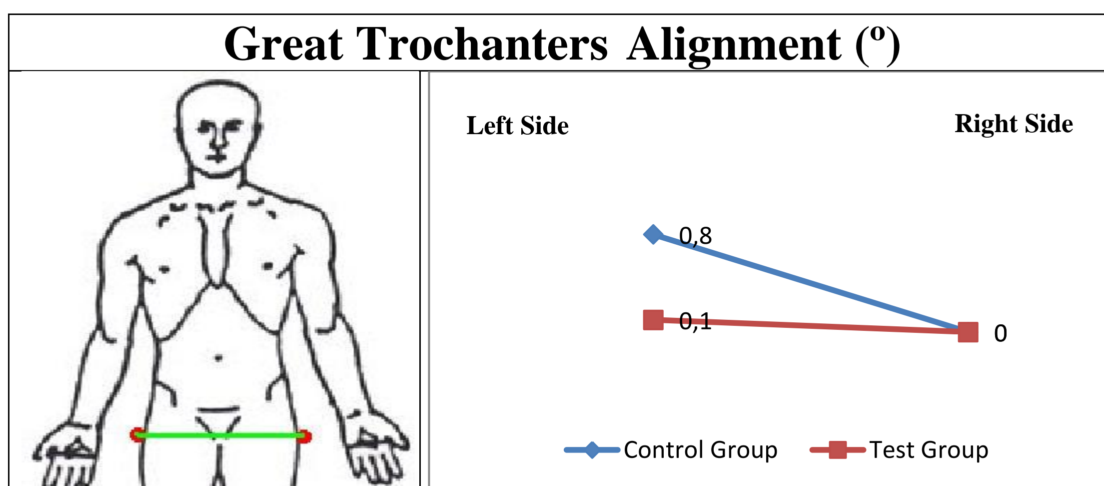
Graph 12: Posture parameter 8.

It can be seen a misalignment of the shoulders in both groups. The non-DD group shows the left acromion 1.8º higher, and in the DD group the left acromion is 1.1º higher, when compared to the right acromion.



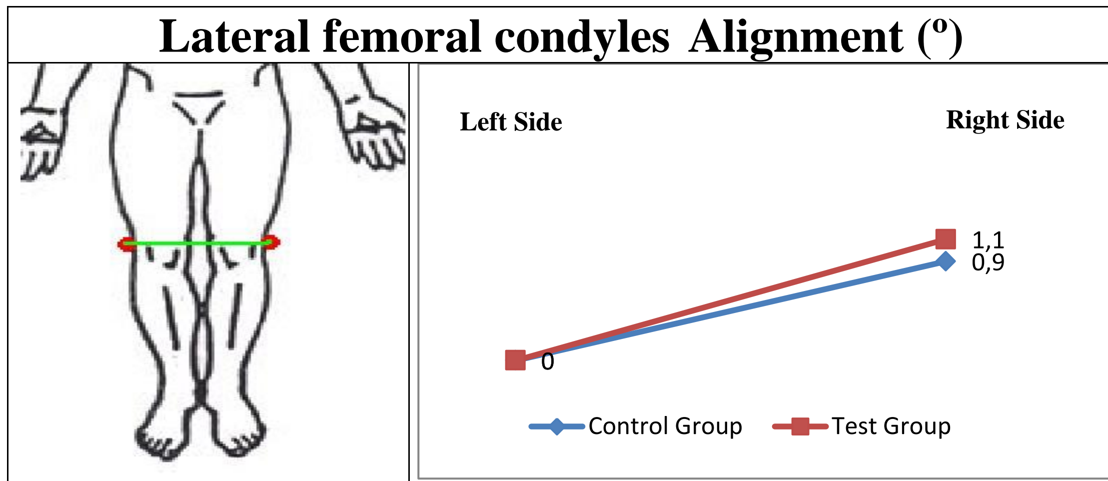
Graph 13: Posture parameter 9.

We can see a correct alignment of the anterosuperior iliac spines in both groups, the differences found of 0.2º (non-DD group) and 0.1º (DD group) higher in the left side are not significant.



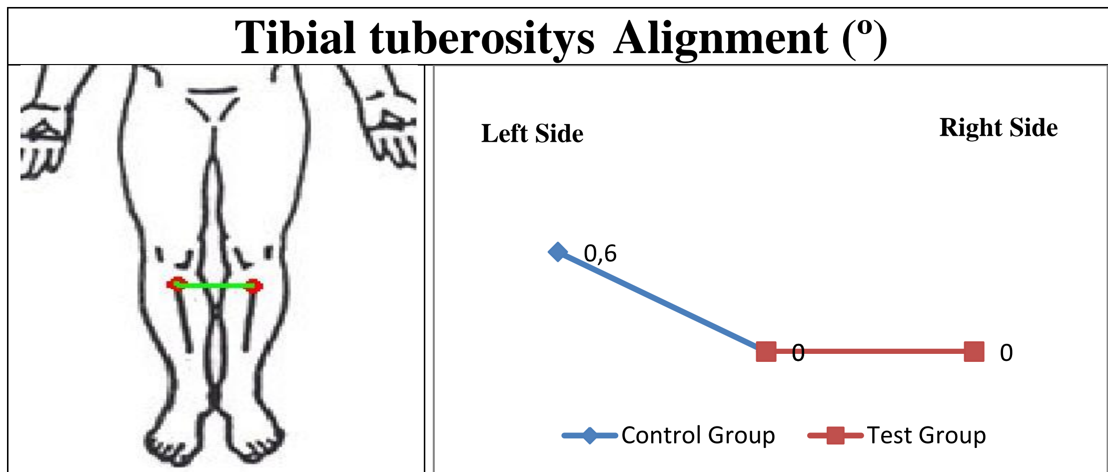
Graph 14: Posture parameter 10.

The great trochanters alignment doesn't show any significant differences. The left great trochanter is higher 0.8º than the right in the non-DD group and 0.1º in DD group.



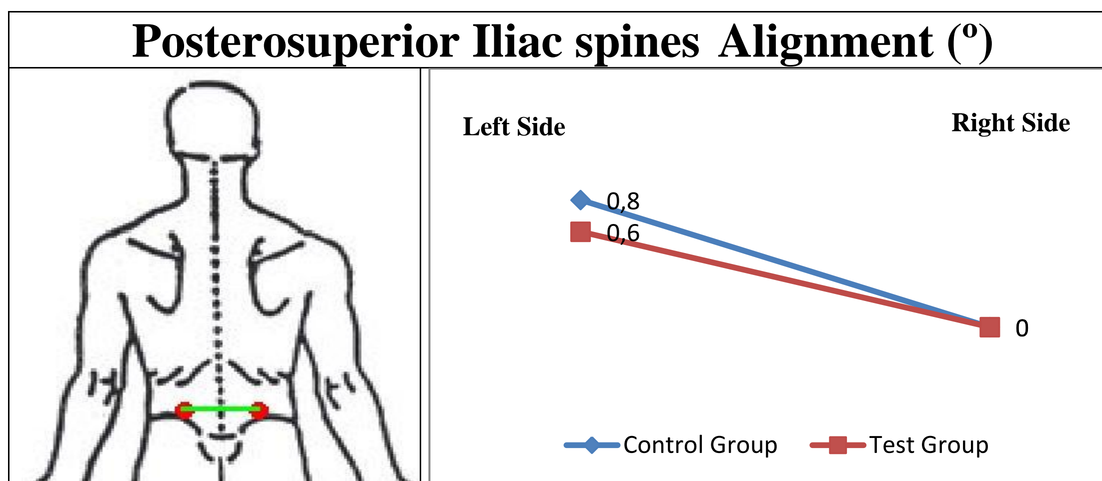
Graph 15: Posture parameter 11.

The right lateral femoral condyle is 0.9º higher in non-DD group and 1.1º in DD group compared to the left lateral femoral condyle.



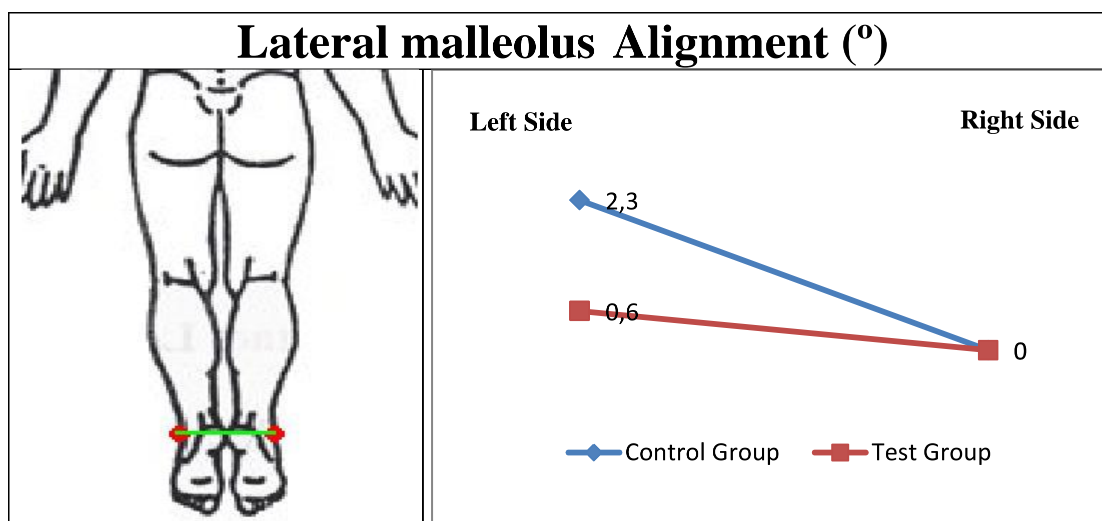
Graph 16: Posture parameter 12.

The non-DD group shows a difference between tibial tuberositys alignment, 0.6º higher in the left side, that is not significant. The DD group show a correct alignment between right and left tibial tuberositys.



Graph 17: Posture parameter 13.

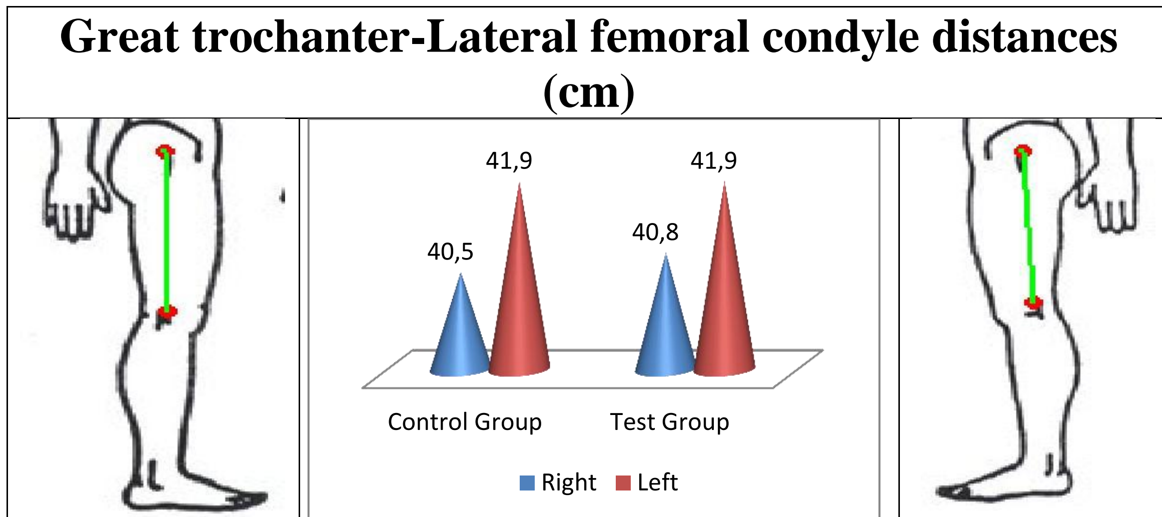
The posterosuperior iliac spines alignment doesn't show any significant differences. The left posterosuperior iliac spine is higher 0.8º than the right one in non-DD group and 0.6º in DD group.



Graph 18: Posture parameter 14.

The lateral malleolus alignment shows some significant differences between groups. In non-DD group the left lateral malleolus is 2.3º higher than the right and in DD group 0.6º higher.

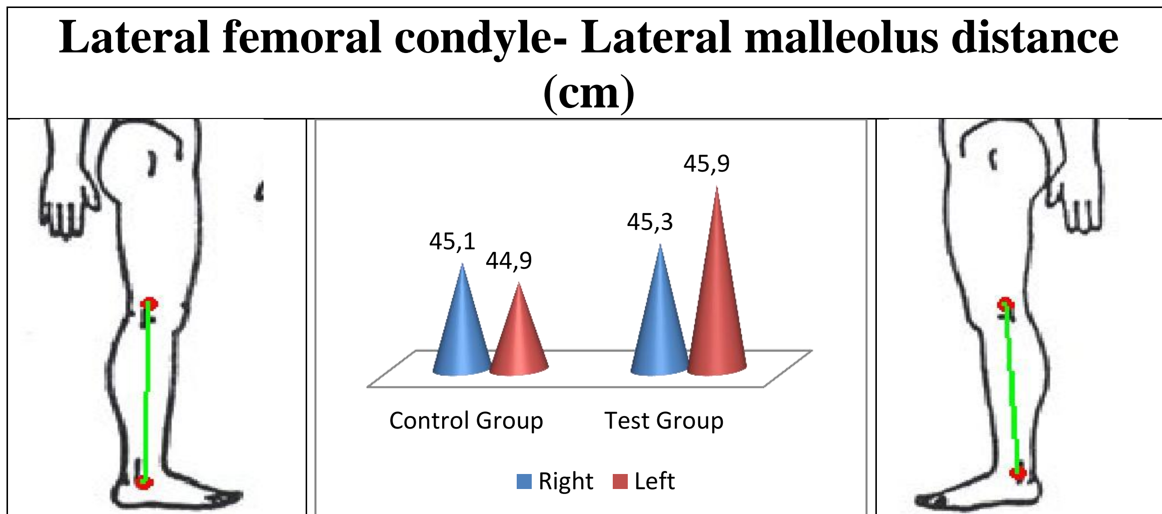
These results show that the subjects without DD has more misalignment between right and left lateral malleolus than the DD subjects.



Graph 19: posture parameters 15 and 17.

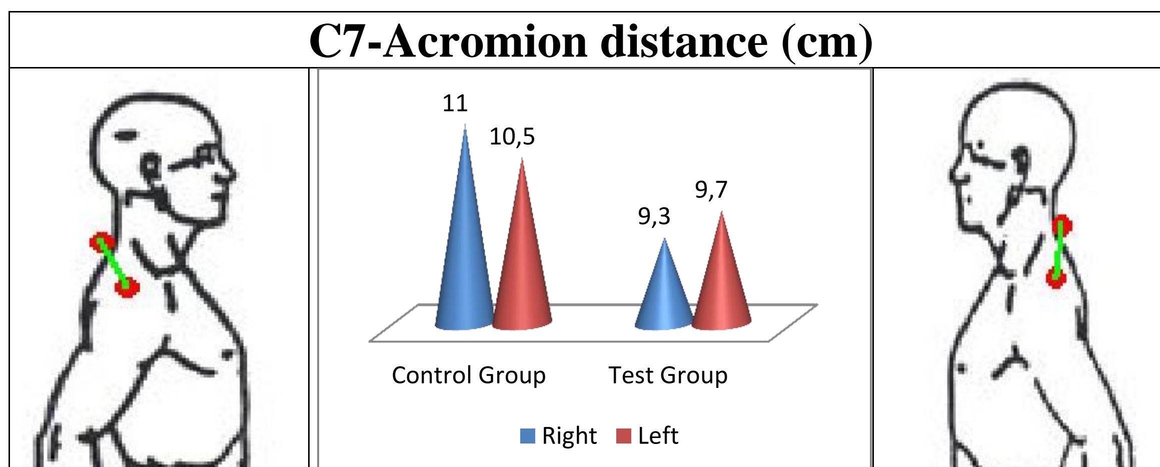
Comparing the hemibodys we can saw that the distance between great trochanter and lateral femoral condyle is higher in the left side in both groups. In non-DD group that difference is 1.4 cm and in DD group 1.1 cm.

In general we may say that this segment distance is higher on the left side in both groups, which could translate a dysmetria at femur level, however the differences found, around 1.0 cm, are not enough to be significant.



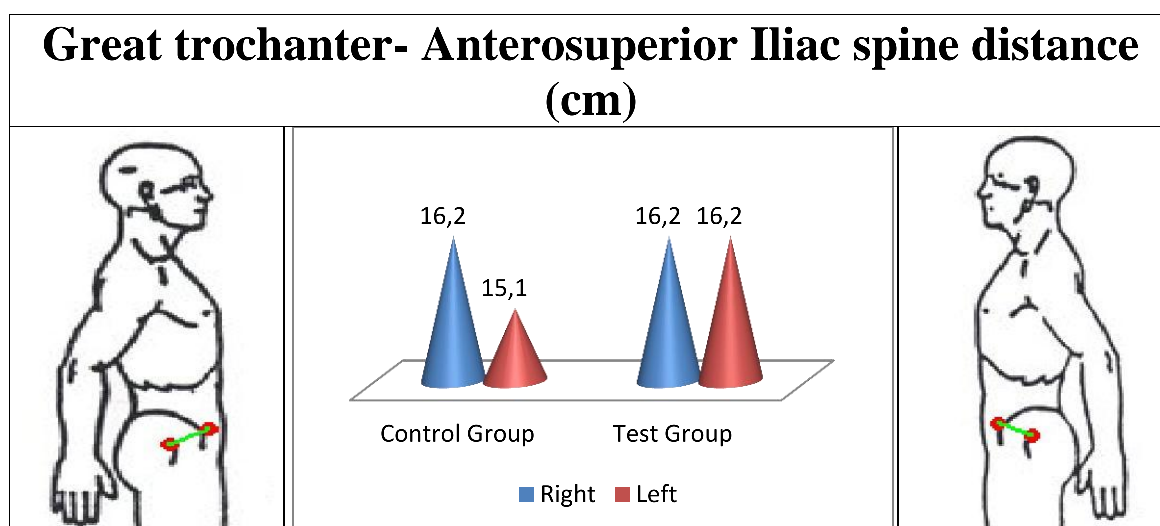
Graph 20: Posture parameters 16 and 18.

There are almost no differences between hemibodys in this segment. In non-DD group we found 0.2 cm higher in right side and in the DD group 0.6 cm higher in the left side.



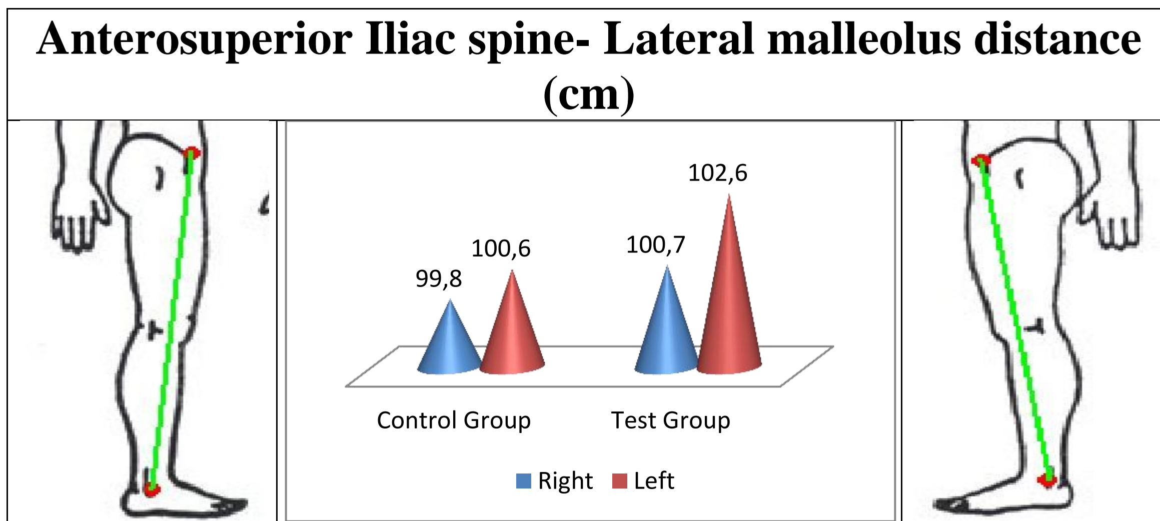
Graph 21: Posture parameters 19 and 21.

The bilateral distances between C7 and acromion don't show significant differences between hemibodys. In non-DD group the distance between these structures is higher 0.5 cm in the right side, and in DD group higher 0.4 cm in the left side.



Graph 22: Posture parameters 20 and 22.

In non-DD group the distance between great trochanter and anterosuperior iliac spine are different in right and left sides, with values of 16.2 cm and 15.1 cm respectively, the difference of 1.1 cm found represents a slightly left hip joint in medial rotation. The DD group shows the same distance between segments in right and left hemibodys (16.2 cm).



Graph 23: Posture parameters 23 and 24.

When comparing the right to the left hemibody, we found some differences, especially in the DD group, in this segment. The non-DD group show a difference of 0.8 cm higher in left side and the DD group 1.9 cm higher also in the left side.

4.5 COG Sway Velocity and Path Analysis

Table 12: Mean and statistical significance of the COG sway velocity and COG path analysis.

	Balance Response	Group	N*	Minimum	Maximum	Mean (±Std. Deviation)	Sig. (p value)
COG Sway Velocity (º/sec.)	No Movement	**Control**	15	0.1	0.5	0.2 (±0.1)	0.080 **
		Test	20	0.1	1.2	0.4 (±0.3)	
	Opening-Closing	**Control**	63	0.1	1.6	0.3 (±0.2)	0.372 **
		Test	63	0.1	1.4	0.4 (±0.3)	
	Right Exc.-Rest Pos.	**Control**	63	0.1	1.1	0.3 (±0.2)	0.077 **
		Test	63	0.1	2.3	0.5 (±0.4)	
	Left Exc.-Rest Pos.	**Control**	63	0.0	1.5	0.4 (±0.3)	0.567 **
		Test	63	0.1	1.9	0.5 (±0.4)	
COG Mean Path (º)	No Movement X	**Control**	15	0.0	0.1	0.0 (±0.0)	0.117 **
		Test	20	-0.1	0.1	0.0 (±0.1)	
	No Movement Y	**Control**	15	-0.4	0.2	0.0 (±0.1)	0.190 **
		Test	20	-0.2	0.7	0.1 (±0.2)	
	Opening-Closing X	**Control**	63	-0.1	0.9	0.0 (±0.1)	0.864 **
		Test	63	-0.3	0.3	0.0 (±0.1)	
	Opening-Closing Y	**Control**	63	-0.2	0.3	0.0 (±0.1)	0.200 **
		Test	63	-0.5	0.6	0.0 (±0.1)	
	Right Exc.-Rest Pos. X	**Control**	63	-1.3	0.2	0.0 (±0.2)	0.959 **
		Test	63	-0.2	0.1	0.0 (±0.1)	
	Right Exc.-Rest Pos. Y	**Control**	63	-0.6	0.7	0.0 (±0.2)	0.447 **
		Test	63	-0.2	0.4	0.0 (±0.1)	
	Left Exc.-Rest Pos. X	**Control**	63	-0.2	0.2	0.0 (±0.9)	0.147 **
		Test	63	-0.2	0.1	0.0 (±0.1)	
	Left Exc.-Rest Pos. Y	**Control**	63	-0.5	0.5	0.0 (±0.2)	0.808 **
		Test	63	-0.4	0.7	0.0 (±0.2)	

*** Valid/Completed repetitions in the 3 attempts.**
**** T-Test Student for independent samples. Significant differences: p ≤ 0.05 at bold and italic.**
 # Mann-Whitney Test for independent samples. Significant differences: p ≤ 0.05 at bold and italic.

All balance responses to mandibular movements show no significant differences between groups.

The COG sway velocity during jaw movements is a little higher in subjects with DD, but still non-significant. The COG mean path during jaw movement don’t have any differences between groups.

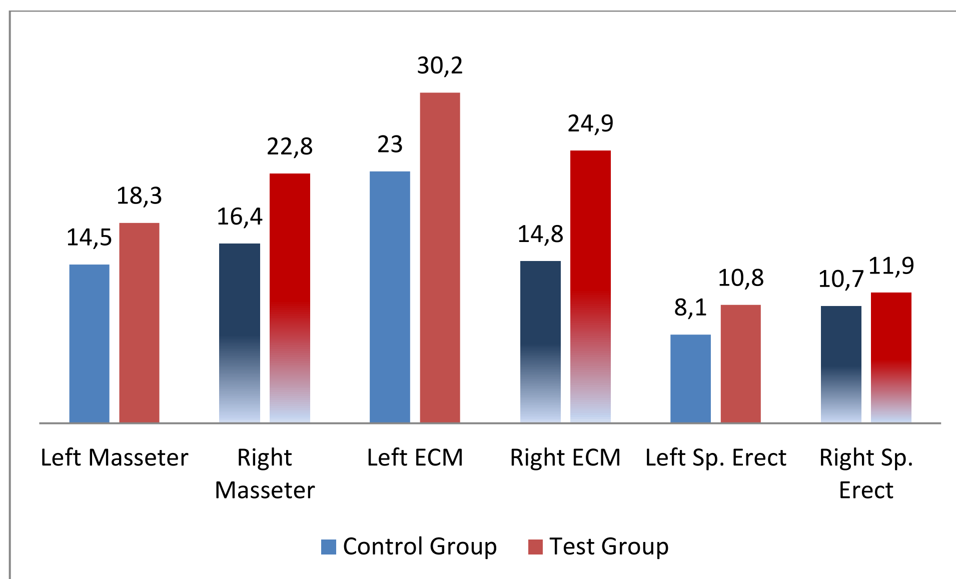
4.6 EMG Analysis

Table 13: Mean and statistical significance of the EMG muscle activation analysis.

	EMG Activation (%)	Group	N*	Minimum	Maximum	Mean (±Std. Deviation)	Sig. (p value)
Opening-Closing	Left Masseter	**Control**	60	0.7	61.8	14.5 (±11.6)	0.174 **
		Test	60	2.9	79.9	18.3 (±17.7)	
	Right Masseter	**Control**	60	2.5	41.5	16.4 (±10.2)	***0.035*** **
		Test	60	1.2	85.7	22.8 (±20.5)	
	Left ECM	**Control**	60	1.9	113.5	23.0 (±24.1)	0.140 **
		Test	60	2.4	111.3	30.2 (±28.6)	
	Right ECM	**Control**	60	1.0	44.8	14.8 (±13.5)	***0.001 #***
		Test	60	1.1	82.4	24.9 (±20.1)	
	Left Spinae Erec.	**Control**	60	2.5	22.1	8.1 (±4.8)	0.130 **
		Test	60	2.4	79.6	10.8 (±13.0)	
	Right Spinae Erec.	**Control**	60	2.8	32.4	10.7 (±7.8)	***0.030 #***
		Test	60	4.1	27.6	11.9 (±5.6)	
Right Excursion-Rest Position	Left Masseter	**Control**	60	0.5	30.3	9.6 (±6.1)	0.082 **
		Test	60	0.0	45.1	12.1 (±9.4)	
	Right Masseter	**Control**	60	0.7	41.0	16.4 (±11.0)	0.487 **
		Test	59	3.1	76.6	18.1 (±15.7)	
	Left ECM	**Control**	60	1.1	28.0	8.9 (±6.3)	***0.022*** **
		Test	59	2.0	88.1	15.5 (±20.6)	
	Right ECM	**Control**	60	2.1	51.5	15.7 (±11.1)	***0.016 #***
		Test	59	1.8	64.6	22.1 (±15.2)	
	Left Spinae Erec.	**Control**	60	2.8	20.6	7.8 (±4.4)	0.119 **
		Test	59	2.3	54.5	10.2 (±10.7)	
	Right Spinae Erec.	**Control**	60	2.8	29.1	10.2 (±7.1)	0.061 #
		Test	60	0.0	40.4	11.7 (±6.7)	
Left Excursion-Rest Position	Left Masseter	**Control**	60	0.4	43.1	12.5 (±9.2)	0.579 **
		Test	60	0.9	50.5	13.7 (±14.6)	
	Right Masseter	**Control**	60	1.1	35.2	9.6 (±8.4)	***0.049 #***
		Test	60	1.1	45.2	11.8 (±9.4)	
	Left ECM	**Control**	60	1.2	76.5	23.3 (±20.1)	0.928 **
		Test	60	1.1	181.6	23.7 (±28.0)	
	Right ECM	**Control**	60	1.0	28.5	7.1 (±6.1)	***0.039*** **
		Test	60	1.6	41.1	9.9 (±8.5)	
	Left Spinae Erec.	**Control**	60	2.4	18.3	7.7 (±4.3)	0.056 **
		Test	60	2.1	74.1	11.0 (±12.7)	
	Right Spinae Erec.	**Control**	60	2.9	30.3	10.3 (±7.2)	***0.017 #***
		Test	60	4.0	28.6	12.2 (±6.0)	

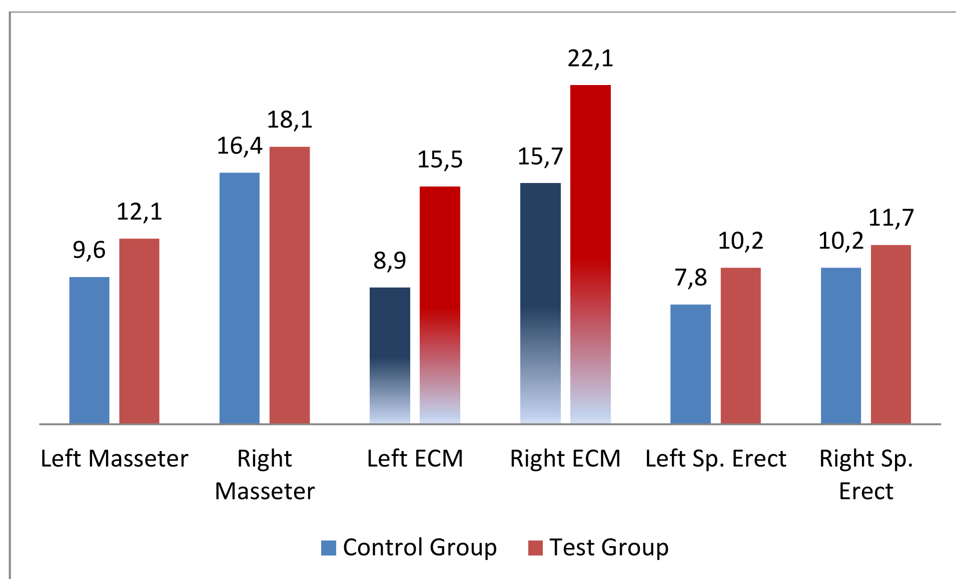
*** Valid/Completed repetitions in the 3 attempts.**
**** T-Test Student for independent samples. Significant differences: $p \leq 0.05$ at bold and italic.**
 # Mann-Whitney Test for independent samples. Significant differences: $p \leq 0.05$ at bold and italic.

The six muscles evaluated for all jaw movements show higher activation in subjects with DD, but particularly, for the opening-closing and left excursion-rest position movements, the activation of the right side muscles are significantly higher in subjects with DD. During right excursion-rest position, both ECM muscles show an activation significantly higher in DD group.



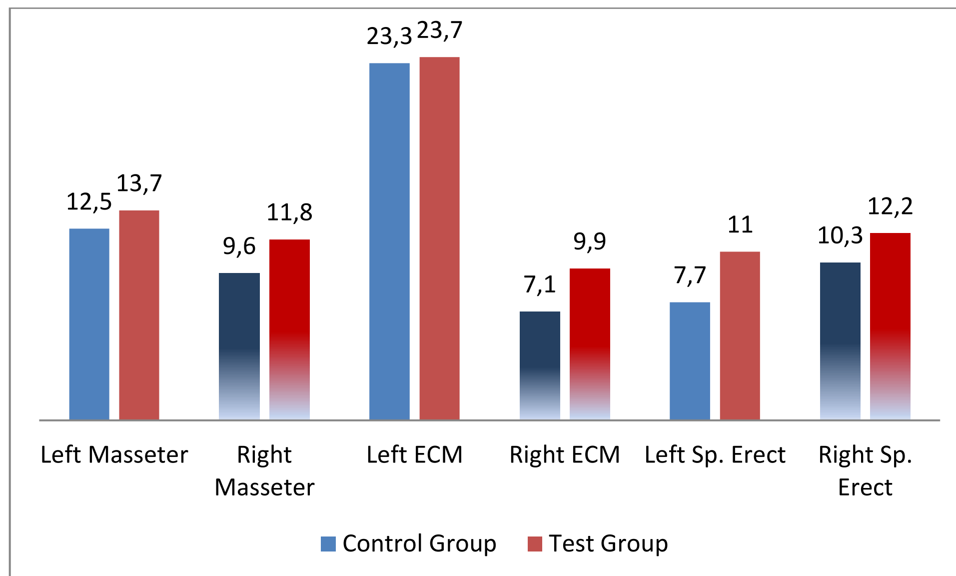
Graph 24: EMG muscle activation during opening-closing movements (%).

In the opening-closing movements the muscle activation of the left masseter, left ECM and left spinae erector don't show any differences between groups. In muscles right masseter (p=0.035), right ECM (p=0.001) and right spinae erector (p=0.030) there are significant differences between groups.



Graph 25: EMG muscle activation during right excursion-rest position movements (%).

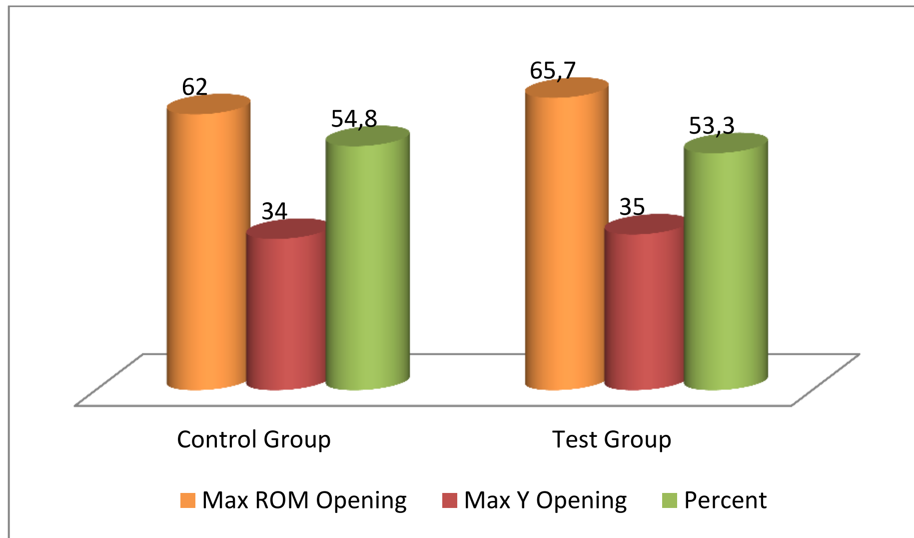
For the right excursion-rest position movements no differences between groups in the activation of the muscles left masseter, right masseter, left spinae erector and right spinae erector. In the muscles left ECM (p=0.022) and right ECM (p=0.016) are differences between groups.



Graph 26: EMG muscle activation during left excursion-rest position movements (%).

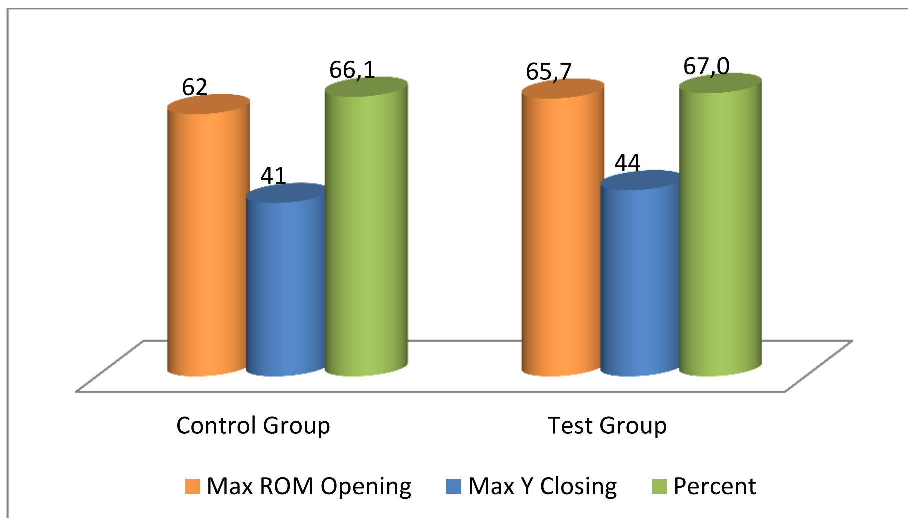
In the left excursion-rest position movements no differences between groups in the muscle activation of the left masseter, left ECM and left spinae erector. The right masseter (p=0.049), right ECM (p=0.039) and right spinae erector (p=0.017) muscles, are significant differences between groups.

4.7 Maximum ROM and Vertical Displacement



Graph 27: Relationship between maximum active ROM opening and maximum vertical jaw displacement during opening movement (mm).

The maximum active ROM is 62 mm in control group and 65.7 mm in test group. Considering that the jaw is the movable part which allows the mandibular opening, it can be seen that from the maximum active ROM, only 34 mm (54.8%) for control group and 35 mm (53.3%) for test group, are obtained in jaw opening. This results indicates that there is a strong component of cervical extension (45.2% for control group and 46.7% for test group) during opening movements.



Graph 28: Relationship between maximum active ROM opening and maximum vertical jaw displacement during closing movement (mm).

The same analysis for jaw closing, it is possible to say that 41 mm (66.1%) for control group and 44 mm (67%) for test group, are obtained in jaw closing. Also here we can observe a strong component of cervical function, in this case, cervical flexion (33.9% for control group and 33% for test group) during closing movements.

5. Discussion

For an accurate results discussion it is important to note that in this study we did not distinguish between disk displacement with reduction and disk displacement without reduction for the test group, and all subjects included in test group were evaluated in order to include the diagnostic criteria for both types of disk displacement.

In fact the subjects, who meet all inclusion criteria for the test group, belonged to the diagnostic criteria for disk displacement with reduction. Therefore, our test group sample, is only representative of a TMJ biomechanics dysfunction, characterized by joint reciprocal and/or reproducible clicks, joint pain precipitated by joint movement, jaw deviation which coincides with the click or no restriction in jaw movements (Dworkin e LeResche, 1992; De Leeuw, 2008).

5.1 Sample Characterization

Respecting to the incidence of TMD, our study is in accordance with literature defined prevalence, regarding to the mean age of the test group of 22.2 (±3.9) years (Solberg, 1985; Egermark, Carlsson and Magnusson, 2001) and regarding to the 4:1 ratio of gender prevalence (17 females:4 males) (Manfredini, Bucci e Nardini, 2007; Cooper e Kleinberg, 2007).

5.2 Kinematic Analysis

5.2.1 Active Jaw ROM

We found values between 51.8-84.5 mm for opening and 5.1-19.7 mm for lateral excursions. These results of the active ROM in opening and lateral excursions are higher than those reported in the literature of 40-55 mm for opening and at least 7 mm for lateral excursion (De Leeuw, 2008).

The assumption is that these values found are related to the individual characteristics of the subjects, such as physical bearing and stature. In fact, when the analysis of individual jaw ROM was undertook, it was found that subjects with best physical robustness had higher values in jaw ROM. Although this relationship has not been found in the literature with adult subjects, these findings are in accordance with the study of Abou-Atme and colleagues, indicating a relationship between the height and the maximum mouth opening in children (Abou-Atme, Chedid, Melis and Zawawi, 2008).

For the differences found between groups (62.0 mm in non-DD and 65.7 mm in DD) in opening active ROM movements, we suppose that they are related to that same physical robustness. Not dismissing the fact that the change in TMJ biomechanics could

cause an abnormal functioning of the bilaminar zone and the other passive structures which could lead to an increasing ROM, we believe that because there is a higher prevalence of subjects with best physical robustness in the DD group, it was found that the DD group has more subjects (12 against 8 in non-DD group) with height exceeding the 170 cm, this is the main reason for the significant differences found.

5.2.2 Jaw Path

Only significant differences were found between groups in some closing movements, which express, at first hand, a greater homogeneity in the opening movements. We will then discuss each of the components of jaw path.

Equally for opening and closing movements, both groups show low values of horizontal jaw displacement, related to a minor deviation from the midline during these movements, in which the DD group shows a slightly higher deviation during closing movements.

The vertical jaw displacement is almost the same for both groups in opening and closing movements. It is noted that both groups have more vertical displacement during closing movements, which should be related with this movement being effected against gravity force and with the number of muscles involved in jaw closing. In the opening only digastric muscles and gravity are effectors of the movement, while in the closing the masseter, the temporalis and the medial pterygoid muscles act. Due to more force produced, it can lead to a less effective movement control, which results in more joint motion, as stated by Koolstra and van Eidjen, 1997.

We found that the moment of higher values of horizontal deviation happens near the end of movement also for jaw opening and jaw closing in both groups, which probably could translate in an adaptation of the disk to the movement. These findings should be more evident in DD group, but it is not strange at all that in a normal and physiologically joint those disk adaptations, near the end of movement, are higher to reach the stable position.

For the horizontal jaw displacement difference from the end to the start point, we found that the non-DD group shows a minor difference in opening and closing movements reaching the start position in alignment with the midline. In DD group it was found that in the opening there wasn't any difference in the alignment, but in the closing there was a misalignment during the movement, reaching the start position with left side deviation in relation to the midline. These findings connected to the findings from the jaw horizontal displacement show that in closing movements the DD group has a little more jaw horizontal deviation than in the opening movements, which means that in general, the closing movements are more instable than the opening movements.

The jaw total of vertical and horizontal displacement in the opening movements, show that there aren't almost any differences between groups. In the closing movement it can be seen that the DD group presents a total amount of jaw displacement higher

than the non-DD group, showing again more instability in closing movements in DD group. Contrary to what would be expected, it was found that the total deviation from the midline, during opening and closing movements, it is the same in both groups, not noticing more movement out of the midline in the DD group.

5.3 Postural Analysis

We found that in general, the postural analysis, doesn't show significant differences between groups. The only parameter with significant statistical differences corresponds to a misalignment of the lateral malleolus in the non-DD group.

The DD group shows minor body posture changes and it was also found that the non-DD group shows higher variability in body posture changes. We will discuss below the body posture findings and relate them with the groups.

5.3.1 Posture Parameters

Both groups show forward head posture, probably related to daily poor postures. Associated to the forward head posture, which leads to a change in head position to have a broader view, it was also found that both groups exhibit extension of the cervical spine. It is important to note that the lowest values were found in the non-DD group, indicating that this group has more postural changes in these structures.

The DD group shows a correct tragus alignment, not noticing any inclination of the head. The non-DD group shows an inclination of the head to the right side, however the values found of 1.5º are not for valuing because it is a negligible value and could be probably be related with measurement errors. If any inclination of the head exists it is in non-DD group, for the left side, as indicated by the three posture parameters discussed next.

The acromion-tragus distance is lesser in the left side in both groups, but the difference is higher in the non-DD group, which may indicate an inclination of the head to the left side and/or a misalignment of the shoulders. Indeed we found a misalignment of the shoulders in both groups, but that misalignment is more noticeable in non-DD groups, in which the left acromion is 1.8º higher than right acromion, and in spite of also be a negligible value, associated to the C7-tragus distance, should be considered a stronger and most valuable finding. The C7-tragus distance is lesser in the right side in both groups, indicating a head rotation to the right, and this fact, although slightly, confirms the inclination of the head to the left side in non-DD group. These findings, showing a minor muscle shortening in the left side, translate little changes in body posture at head and shoulders level peculiarly in non-DD group.

Also at shoulders, the C7-acromion distance shows that the right acromion are in a more anterior position than the left acromion in non-DD group and in DD group is the

left acromion in a more anterior position, however these values are so small that do not represent true body posture changes.

In coronal plan the anterosuperior iliac spines, great trochanters, lateral femoral condyles, tibial tuberositys and posterosuperior iliac spines show a good alignment in both groups, not noticing any asymmetrical elevations between these bilateral structures.

In the other hand, the alignment of lateral malleolus shows an asymmetrical elevation of the left malleolus only in the non-DD group. This could be explained by the findings in great trochanter-anterosuperior iliac spine distances, showing that this distance are lesser in left side, indicating a medial rotation of the left hip joint, which leads to a further support in the medial arch of the foot, elevating the lateral malleolus. The DD group shows a correct alignment of the lateral malleolus and also shows a same distance between right and left great trochanter-anterosuperior iliac spine.

The great trochanter-lateral femoral condyle distances and lateral femoral condyle-lateral malleolus distances, that could indicate leg dysmetrias, are higher in the left side in both groups, however the values found are so small that they are not enough to be relevant.

The anterosuperior iliac spine-lateral malleolus distances are higher in the left side in both groups, but although slightly, are more evident in DD group, which could indicate a support load predominantly in the right leg.

In summary, the changes found are not determinant of significant body posture changes in any studied group, and if we had to see in detail, we would say that the non-DD group shows more body posture changes than the DD-group.

Our study is in accordance with literature in respect to the relationship between TMD and forward head posture (Ayub, Glasheen-Wray and Krauss, 1984; Friedman and Weisberg, 1982; Janda, 1981; Goldstein, Kraus, Williams and Glasheen-Wray, 1984; Urbanowicz, 1991; Gonzalez and Manns, 1996; Miranda et al. 2010), but we found that the subjects without TMD also show forward head posture, not being this change in head position an able feature to describe TMD patients.

Also according with Perinetti, 2007; Iunes et al. 2009; Manfredini, Castroflorio, Perinetti and Guarda-Nardini, 2012, we didn't find significant body posture changes in disk displaced TMD patients.

Other body posture changes described in literature among TMD patients like unleveled shoulders (Clark, Green, Dorman and Flack, 1987; Fuents, Freesmeyer and Henriquez, 1999; Rocabado and Tapia, 1987), rotation and/or inclination of the head (Farias, Alves and Gandelman, 2001), postural deviations in the pelvis and hip joint (Munhoz and Marques, 2009), weren't found in the DD group in our study.

5.4 COG Sway Velocity and Path

The small values and the non-significant differences between groups found in the COG sway velocity and in the COG path during jaw movements, indicates that the DD group have the balance and the posture control mechanisms well preserved, not noticing any balance impairment due to this specific TMD.

Regarding to the relationship between body posture and balance, we can observe that the results obtained in body posture supports the results obtained in the balance platform, in which the absence of uncoordinated actions of external and internal forces able to move the center of mass, results in the absence of imbalance to the musculoskeletal system.

Perhaps we could have other results if the assessment of body posture changes and balance was made dynamically, with dynamic involvement of the body segments (like in gait), but so far as we can see with this posturographic assessment instruments, our study is in accordance with literature (Perinetti, 2007; Ferrario, Sforza, Schmitz and Taroni, 1996; Perinetti and Contardo, 2009; Manfredini, Castroflorio, Perinetti and Guarda-Nardini, 2012), showing no significant relationships between body posture, balance and TMD.

5.5 EMG Analysis

The muscle activation during jaw movements is higher in DD group, suggesting that in general, these subjects recruit more muscle fibers than the subjects from the non-DD group. Once the muscles are primarily responsible for maintaining stable the mandibular movements, as stated by Koolstra in 2002, this could be explained by a less stable pattern of movement in DD group, which leads to a higher muscle activation to guide and control the movement, ensuring the best as possible articular stability.

In opening-closing movements the muscle with more activation is the left ECM, followed almost similarly by right ECM and right masseter, with this trait being common for both groups. The significant differences found between groups in right masseter, right ECM and right spinae erector, suggests a higher prevalence of subjects with injury in the right TMJ in the DD group (confirmed by the disk displacement diagnostic distribution), in which the significant muscle activation differences are higher in DD group due to a need for increased activation in the right side in order to compensate the functional imbalance and promote the movement stable, trying to maintain the desired performance levels.

In non-DD group we can also see a significant (8.2%) higher activation of the left ECM when compared to the right ECM, what could be explained by a slightly inclination of the head to the left side, as mentioned in the body posture section.

As expected the muscles showing higher activation during right excursion-rest position is the right masseter and the right ECM for both groups. The significant differences found between groups in right and left ECM muscles could be interpreted by the need of more activation in the right side by the DD group in the right ECM. If we analyse the left ECM we can see that its activation is standing out in DD group, acting as a protective mechanism. The contralateral muscle co-contracts to help the movement, enabling better motor control preserving and protecting the integrity of the right side TMJ.

The muscle with more activation in left excursion-rest position movements is clearly the left ECM followed by left masseter in both groups. Significant differences between groups were found in right masseter, right ECM and right spinae erector, like in opening-closing movements, which could be explained by the same need for increased activation in the right side to compensate the functional imbalance. In this case, unlike the right excursion-rest position, we don't see a greater influence of the contralateral ECM (right), because the major activation muscles are in the non-injury side, which does not need as much protection from the contralateral muscle.

Another possible explanation for the significant differences found mostly in the right side muscles and looking to the higher prevalence of subjects with injury in the right TMJ in the DD group may be the biomechanical disorder, in which at some point, the right side muscles need more activation to overcome the obstacle (disk displacement).

Summarizing, in all evaluated jaw movements, the ECM muscles seems to have an important role, showing higher percentage of activation in both groups. These findings could represent a major role of ECM muscles on the stabilization of the head to allow jaw movements.

5.6 Maximum ROM and Vertical Displacement

The relationship between maximum active ROM and vertical displacement show a strong influence of cervical spine in both groups, verifying accessory movements of cervical extension during opening and cervical flexion during closing movements. However, we must relativize these results, because this active ROM in opening and closing movements, is not representative of all daily and functional movements of the stomatognathic system, only being reproducible during yawn and maybe in the introduction of some food in the mouth. In further studies, a proper cervical spine stabilization should be used, in order not to intervene in the performance of the jaw movement.

5.7 Implications for the Physiotherapy and Study Limitations

The conservative treatment is considered the most suitable and effective treatment for TMD patients. Saying that, the first implication for the physiotherapy is it important role in the treatment of this health condition.

The physiotherapy in TMD is intended to reduce the inflammation, decrease de musculoskeletal pain and restore the oral motor function and needs to be seen as a key role asset by physiotherapists (which need to be increasingly trained in this area), by dentists (which need to choose the best treatment modalities in function to the real patient needs) and by musculoskeletal doctors (which need more information about this condition so that they can send this patients to the best health care practitioners).

In respect to the present study, we get a kinematic notion of greater instability in the jaw closing movements; the absence of significant body posture changes and balance impairments; and a compensatory pattern of muscle activation that can guide future interventions and adjust the various techniques for better motion control and better pain-free oral function in patients with TMD.

The study limitations are related with the sample size (which should be larger) and may lead to low variability of the results; with the sample selection, which was obtained by convenience, and may not be representative of the clinical condition because to date none of the subjects was submitted to any kind of treatment for TMD, which can mean an early disk displacement with reduction development stage; with some possible measurement and experimental setup errors; and with possible outside factors like pain during movement or any other cause that could affect motion performance. Related to these facts, some of the statistic significant differences found could be merely due to chance, with the need of further studies with greater samples to better clarify those findings.

6. Conclusion

In previous chapters we presented and discussed the findings of some assessments that aimed to verify if an internal biomechanical disorder of the TMJ, in this case disk displacement with reduction, may affect body posture and balance. The study led us to get deeper into such complex issue, because it allowed to characterizing the patterns of the jaw movements and assessing the muscle activation during jaw movements in subjects with disk displacement in comparison to subjects without TMD.

With respect to the clinical research questions/hypothesis we have set at the beginning of the study, the following conclusions can be drawn:

Subjects with DD show higher active ROM in opening and lateral excursions jaw movements, but the difference with control subjects is only significant in the opening jaw movements, likely related to a better physical robustness and higher stature.

The pattern of the jaw depression (opening) and elevation (closing) is similar in both groups, but in subjects with DD the closing movements are more instable than the opening movements, related to a less effective movement control to counteract the force of gravity and the disk displacement.

The total of jaw displacement for depression and elevation movements is the same for both groups. In the depression movements, subjects without DD show slightly higher total jaw displacement and, on the contrary, in the elevation movements subjects with DD show slightly higher total jaw displacement.

There are no significant body posture changes at head level in subjects with DD when compared to subjects without DD. Both groups show forward head posture and cervical spine extension, without any other body posture changes at head level.

There are no significant body posture changes at the whole body level in subjects with DD when compared to subjects without DD. Notwithstanding that, subjects without DD, in general, show more body posture changes than subjects with DD.

There are no significant posture changes between the right hemibody and the left hemibody in subjects with DD. It was described only a slightly higher anterosuperior iliac spine-lateral malleolus distance in the left hemibody, which could indicate a support load predominantly in the right leg in subjects with DD, not at all significant.

There are minor significant body posture changes between the right hemibody and the left hemibody in subjects without DD, especially in the lateral malleolus alignment and in the great trochanter-anterosuperior iliac spine distance, being this distance lesser in the left hemibody, indicating a medial rotation of the left hip joint,

which by its turn, leads to a further support in the medial arch of the foot, elevates the left lateral malleolus.

The displacement velocity of the center of mass during the jaw movements is slightly higher in subjects with DD, but it must be noticed that the described values are so small that they are not enough to be relevant.

The average path of COG during jaw movements does not show any differences between subjects with DD and subjects without DD. This finding, together with the above findings on the displacement velocity of the center of mass, indicates that the balance and the posture control mechanisms are well preserved, not noticing any balance impairment in subjects with DD.

The bilateral muscle activation of the masseter muscles, sternocleidomastoid muscles and spinae erector muscles during jaw movements is higher in subjects with DD, likely related to a less stable pattern of movement which leads in a higher muscle activation to guide the movement and ensure the best as possible articular stability. Significant differences were found with higher activation in subjects with DD in right side muscles, possibly due to a higher prevalence of subjects with injury in the right TMJ. The presence of right DD may force an increased muscle activation in the right side to overcome the obstacle (disk displacement) in order to compensate the internal biomechanical disorder and maintain a steady movement.

The above observations indicate that disk displacement with reduction should not be regarded as a pathological condition per se, but it may be viewed as part of a set of signs and symptoms that require an accurate musculoskeletal and psychosocial assessment towards an earlier diagnosis for reduction and control of the functional limiting factors. In this direction, it seems that the relevant set of limiting signs and symptoms deserve a particular attention by health care practitioners involved in the assessment and treatment of TMD, in order to define effective therapeutic options.

In the clinical setting, it is quite common to meet patients showing concern in reaction to their condition, due to their personal beliefs and fears that this condition is irreversible, uncontrollable and may lead to facial deformities. Thus, it is essential that healthcare professionals are informed and, by their turn, inform TMD patients about their condition, so they can understand that, in general, disk displacement is a condition with a good prognosis and with minimal impact on daily life, allowing them to take more correct preventive attitudes.

Following this study and keeping in mind that in some cases a disk displacement with reduction may progress to displacement without reduction, we recommend to conduct a similar study on TMD patients with DD without reduction. Presumably, the active ROM, the jaw movement patterns and probably also the muscle activation, could bring new and different data, which may or may not, influence the body posture and balance.

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