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Licenciatura em Ciências da Engenharia Biomédica

Development of a normative base in pathologies of the rheumatologic forum based on posturography and electromyography

Dissertação para obtenção do Grau de Mestre em Engenharia Biomédica

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À minha mãe e avó.

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Abstract

Maintaining a stable standing position and body orientation are fundamental tasks to perform everyday activities and ensure the quality of life. The ability to control these conditions can be damaged by various conditions, for example rheumatologic diseases, muscular diseases, aging, vestibular diseases and others. For that reason is important to know how the postural control reacts to different situation and how is affected by different anomalies like those that were mention before.

The main goal of this project is to define the normal population pattern of upright standing position using posturography and electromyography (EMG). A protocol was developed for achieve this goal and 39 healthy subjects participated in the study. An extra 10 subject diagnosticated with anquilosant spondylitis took part in the study.

Results obtained on this study were very interesting. It was concluded that right Rectus Abdominis played an important role in maintaining the upright standing position, by its constantly activation along the conditions of the protocol. Analyzing center of pressure (COP) and EMG parameters, it was concluded that visual feedback has an important role in maintaining the postural control. By analyzing the 10 extra subjects, it was concluded that EMG is an essential tool in order to compare the two groups and identify differences.

Keywords: Posturography, Electromyography, Postural Control, Balance, Ankylosing Spondylitis.

Resumo

Manter o equilíbrio e a postura corporal são tarefas fundamentais para realizar atividades cotidianas e garantir a qualidade de vida. A capacidade de controlar estas condições pode ser danificada por várias razões como por exemplo, doenças reumatológicas, doenças musculares, envelhecimento, doenças vestibulares, entre outros. Devido a isto, é importante perceber como reage o sistema de controlo postural a diferentes destabilizações e a diferentes anomalias que poderão ser surgir neste sistema.

O objetivo principal deste estudo é definir o padrão normal da posição ortostática utilizando a juntando a posturografia com a electromiografia (EMG). Um protocolo foi desenvolvido de maneira a atingir este fim, e 39 indivíduos saudáveis participaram no estudo. 10 sujeitos extra, diagnosticados com espondilite anquilosante participaram também no estudo.

Os resultados obtidos neste estudo foram bastante interessantes. Concluiu-se que o Rectus Abdominis desempenha um papel fundamental na manutenção da posição em estudo, devido à sua constante actividade durante todas as tarefas realizadas durante o protocolo. Analisando os parâmetros do centro de pressão (COP) e de EMG, concluiu-se que o feedback visual tem um papel importante na manutenção do controlo postural. Ao analisar os 10 sujeitos extras, concluiu-se que o EMG é uma ferramenta essencial para a comparação dos dois grupos e identificar as diferenças entre eles.

Palavras-Chave: Posturografia, Electromiografia, Controlo Postural, Equilíbrio, Espondilite Anquilosante.

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Acronyms

AS	Ankylosing Spondylitis
CEDOC	Chronic Diseases Research Center
CNS	Central Nervous System
COG	Center of Gravity
COP	Center of Pressure
FCT-UNL	*Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa*
MVC	Maximum Voluntary Contraction
RMS	Root Mean Square

1

1. Introduction

In this section of the document, a brief description of the themes that were addressed in the project is made.

This chapter is divided in three different parts: motivation, objectives and dissertation structure.

Regarding motivation, brief introduction to the present study and the importance of the same are done. In objectives, the main goals of the study are described. Finally yet importantly, dissertation structure of the structure of the present document is presented.

1.1. Motivation

With all the tasks that daily life requires, body position is still evolving and changing. The upright standing position is one of the positions that is controlled by the postural control system and is one of the most important positions for ensuring a good quality of life [1]. It is perceived by many that maintaining this position is a task that does not require much effort however, it is known that maintaining the upright position is a task, that requires the coordination of many different systems, for example, the motor system, sensory system and the central nervous system [2][3]. This ability to maintain the correct posture can be affected by many different factors, and therefore subjects with problems in posture have a higher risk of falling and have a decreased quality of life [4][5].

In order to maintain a correct posture and equilibrium, the correct functioning of the muscles used by the posture and balance systems is very important. Trunk muscles have an important role in maintaining postural control and stability, with the coordination between them ensuring the correct posture of a subject [6][7]. However, there were not found many studies using electromyography (EMG) at trunk level in order to evaluate postural control system, with most of the studies found on lower limb EMG [8]. For this reason, an opportunity for innovation in field of posture and balance control arose.

In order to evaluate postural control and equilibrium changes, researchers commonly use a noninvasive technique called posturography. Posturography is not a recent technique of postural analysis, with studies dating back to 1970, using force platforms as the preferred instrument to evaluate the posture and balance [2].

Through force platforms, center of pressure (COP) can be extracted. This is defined as the representation of all the vertical forces in the platform, done by the human body in order to maintained balance. The analysis of this metric can provide a better understanding regarding the adjustments of the human body performs in order to not suffer a fall [2][9].

Over the years, posturography has been used as a comparison of tools. It is very common to compare a group of people with pathology with a group without pathology, comparing groups of subjects with different age range, or comparing genders. However due to the lack of standardization of posturography tests, there are too many different conclusions and opinions in the literature regarding this type of test [10][11][12][13]. Without a standard protocol or gideline, different tests are done with a different number of repetitions and different time acquisition, leading to a big variety of signal parameters, which could lead to misinterpretation of the results [10][12][14].

Taking into consideration all the previous information, the need for the evaluation of posture and consequently its standardization arises. By standardizing not only a protocol but also the normal values for posture in a healthy population, it is possible to use these values in a clinical environment to help identify occurrences of compare it in a clinical setting, with pathologies that can create impairments regarding the maintenance of posture.

One of the factors that can cause postural changes is rheumatologic diseases. One type of rheumatologic disease is rachialgia, and it is estimated that 80% of actual society suffers from this type of disease [15].

One example of rheumatologic disease is ankylosing spondylitis (AS). This is a chronic rachialgia that affects about 1% of the world's population. Patients with this pathology start to show symptoms as young as 24, the average age for the diagnose of this disease. This disease is characterized by the fusion of the various vertebrae of the vertebral column, with these patients presenting a rigid spine with little freedom of movement [16]. For this reason, causing difficulties in the posture of the patient and difficulty in maintaining the balance of the same [16][17].

During the realization of this project, the opportunity arose to compare healthy subjects with patients suffering from ankylosing spondylitis. Through this comparison, the main goal of the study, the development of a normative basis for posture in healthy subjects, can be validated.

This project falls within the scope of Biomedical Engineering and aims to develop a normative basis, based on posturography and EMG, for a group of healthy subjects. This project was developed at FCT-UNL, more specifically in the Biomedical Engineering Laboratory of the Department of Physics. The acquisition of the data was performed at the FCT-UNL Physics Department.

Besides the analysis in a group of healthy individuals, it was also possible to evaluate a group of individuals with ankylosing spondylitis, using the same protocol used on the group of individuals without pathology. The acquisition of data regarding the pathologic individuals was performed at the Chronic Diseases Research Center (CEDOC).

For the acquisition of the data it was use a force platform and an EMG apparatus. Both the force platform and the device to acquire the electromyographic signals (BiosiganlsPLUX) were made available by the company PLUX.

1.2. Objectives

The main goal of this thesis is the development of a normative basis combining the techniques of electromyography and posturography. For that purpose, this project aims to achieve the following goals:

- Definition of the biomechanical and electrophysiological parameters to be analyzed;
- Development and optimization of protocol for the acquisition of biomechanical and physiological parameters;
- Validation of the protocol in laboratory context; Acquisition of data in a sample of people without pathology;
- Analysis of biomechanical and electrophysiological parameters and correlation of data demographic;
- Development of a clinically relevant normative database for a sample of subjects without pathology;
- Elaboration of the posture profile of the person without pathology, in the standing positions;

With the development of this study, the opportunity arose of the evaluation of a group of subject with ankylosing spondylitis.

1.3. Dissertation Structure

The present Master's thesis consists of five sequential and interlinked chapters (including chapter 1), where it is presented the theoretical fundaments, methodology of the study, their results and discussion. The document is structured as follows:

- Chapter 2 addresses some basic concepts of postural control and equilibrium, muscle activation, EMG, and posturography
- Chapter 3 describes a review of some studies already performed regarding postural control, both at the electromyography level and at the posturography level.
- Chapter 4 describes the instruments, the protocol and data analysis.
- Chapter 5 describes the main results of the study.
- Chapter 6 describes the discussion results obtained on the present study.
- In Chapter 7 summarize the main conclusions regarding the work developed and some aspects that can be taken into account in future projects.

2

2. Theoretical Background

In this chapter, important theoretical concepts will be introduced in order to understand the basis of the study. In brief way themes like postural control and balance, factors that can interfere with the postural control and, the instruments used to evaluate postural control and posture, will be addressed.

2.1 Postural Control and Balance

Posture is defined as a state of equilibrium between muscles and bones in order to maintain the human body joints in a correct position [18][19][20]. There are two types of body posture: static body posture and dynamic body posture. Static body posture is considered the state of equilibrium of the human body during quiet position, for example during upright standing position. In the other hand, a dynamic body posture is considered the state of equilibrium of the human body during some type of body motion [20].

Balance is a distinct concept from posture however, they are related. By maintaining a correct posture the human body can balance itself and not suffer a fall. Balance is defined as the ability of the human body to control the center of mass within the limits of stability. Although the center of mass is within the limits of stability, is normal, even in a quiet position, that there is some body oscillation [19][21].

The postural control system is the system that control posture and balance. It coordinates information from various systems, such as the motor system, the sensory system (visual system, vestibular system, and somatosensory system) and the central nervous system [2][3][22]. These three systems are especially important.

The sensor system is responsible for receiving the outside stimulus. After received, the sensor system sends the information to the central nervous system. This has the task of decoding the information and transmits it to the motor system. When the information arrives at the motor system, the muscles have the task of responding accordingly to the stimulus. In posture control, this response is responsible for the stabilization of the person's center of mass. Maintaining a stable standing position and body orientation are fundamental tasks to perform everyday activities and ensure the quality of life [12][23].

The postural control system has two main functional goals: postural equilibrium and postural orientation. Postural equilibrium concerns to the stabilization of the center of mass of the human body so that even if there is an outside stimulus destabilizing it, the center of mass is maintained in the limits of stability. Postural orientation involves the coordination between all the sensory systems and motor system so that the human body is always aware where it is in space and what is around it [2][21][24].

Upright standing position is an equilibrium position that is controlled by the postural control system. By the coordination between all systems, the human body can stand in an erect position without suffering a fall [25].

Trunk muscles have an important role in maintaining posture and stability during upright standing position. These are always slightly activated during standing in order to compensate the gravity force effecting on the human body. The coordination between them ensures the correct posture of the subject [7][26]. According to Bergmark [27], there are two important groups controlling trunk posture and movement. The first group is directly attached to the lumbar vertebrae and can provide spinae segmental stability. In this group of muscle, lumbar multifidus, transversus abdominis and the internal oblique muscle are included. The second group is responsible for trunk movement and produces the torque of the torso. This group, unlike the previous one, is not directly attached to the lumbar spinae. The main goal of this group is provide general trunk stability. Rectus abdominis, external oblique and thoracic erector spinae muscle are part of this group. It has been shown that different postures may lead to different muscle activation [28].

2.2 Factors related to changes in posture and balance

There are many reasons that may cause changes in posture and balance. Neurobiological problems in the peripheral or central nervous systems may cause some damage in the motor control system. Also, the vestibular system can be damaged, causing problems to the balance of the person. Or even muscle weakness caused by some muscular diseases. Age plays an important role as well [4][5]. The following topics are related to the factors that have the bigger impact in changes in posture and balance.

2.2.1 Aging

For maintaining a correct postural balance, the coordination between different systems is required. However, with aging, many systems can be damaged and with that, come complication to maintaining balance. Is it widely known that older people suffer from multiple impairments such as multi-sensory loss, muscle weakness, orthopedic constraints, or cognitive difficulties.

One of the systems that is very important in maintaining balance and postural control is the sensory system [29]. This system is also one of the most damaged systems in older persons. Like it was said before, this system works as a receptor of outside information. If there is some damage in the receptor system, the overall response to the outside stimulus is delayed or nonexistent. When compared to younger subjects, older subjects have longer postural responses, and consequently, have a higher body oscillation [29][30].

With aging, muscular weakness also increases, increasing the difficulty for the muscles to produce stronger responses that can maintain the balance of the subject. As a result, older people have higher risks of falling and have a decreased quality of life, making more difficult to perform everyday activity [31][32]. Figure 2.1 represents wall the impairments that aging carry along.

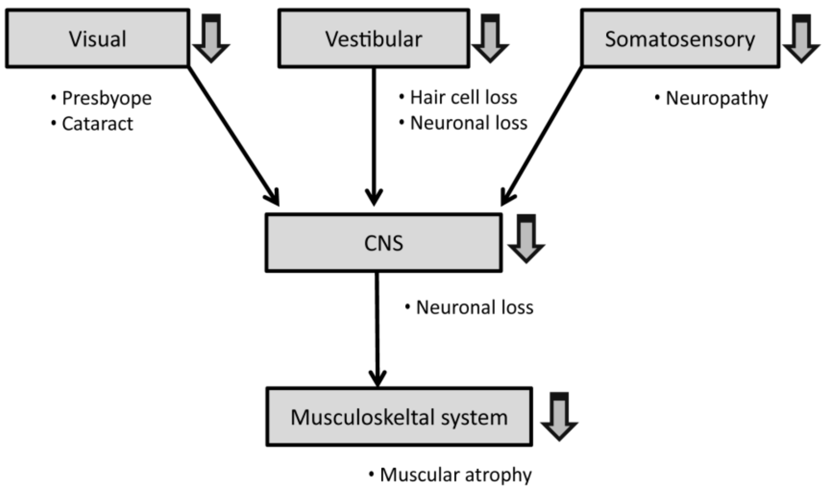

Figure 2.1 - Important resources for maintaining postural stability and balance. Older subjects have higher risks of damaging one of these resources, making it more difficult to maintain a correct posture and ensure the quality of life (Adapted from [30]).

Hageman et al. [33] performed a study where the main goal was to verify the differences on postural control measures in two groups of subjects with distinct ages. The younger group had ages between 20 and 35 years old, while the older group had between 60 to 75 years old. In total, 48 subjects were analyzed. The study showed that older subjects demonstrated bigger amplitudes in body oscillation and longer reactions durations when compared with younger subjects.

2.2.2 BMI

The body mass index (BMI) is a measure of relative weight that has in consideration the mass and the height of the subject (kg/m^2). From the BMI calculation, the subject is underweight, overweight or if the subject is normal range (see Figure 2.2) [34].

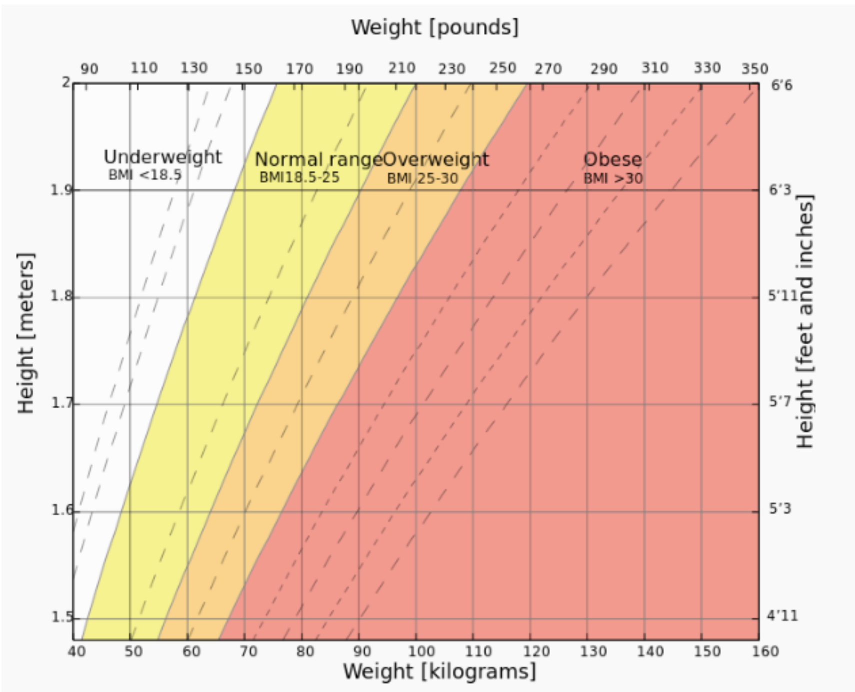

Figure 2.2 - Weight vs height plus the BMI classifications and boundaries. (Adapted from [34]).

Some authors consider that a higher BMI and higher body proportions may lead to some postural adjustments and consequently a higher difficulty to maintain balance. However, there were not found many studies related to the relationship between BMI and changes in postural control [35].

In a study performed by McGraw [36], 20 young boys with an age between 8 and 10 years were evaluated. 10 of the boys were obese and 10 were not obese. The author concluded that obese boys had higher body oscillation amplitudes compared to not obese boys. The authors suggested that higher BMI and higher body proportions cause more instability and more difficulties in maintaining balance.

2.2.3 Physical Activity and Exercise

Physical activity is any body movement that can produce energy expenditure. Activities such as walking, heavy house working, gardening, swimming or dancing are considered physical activities. On the other hand, exercise is a planned activity for the purpose of improving or maintaining components of fitness [37].

It is proved that maintaining an active life style improves the overall quality of life, by increasing muscle strength, bone density, and functional ability. As a result, the practice of sports improves balance and postural stability, prevents some injuries, and reduces the risks of falling [37].

2.2.4 Diseases on Postural Control Systems

Like it was previously mentioned, the postural control system requires the coordination between other different systems: sensory system, central nervous system (CNS) and motor system. Due to this fact, any changes or disturbance in any of these systems can cause difficulties in balance and changes in postural control [38].

The visual system, somatosensory system, and vestibular system are subsystems of the sensory system. The coordination between the inputs that arrive at these subsystems allows for body awareness in relation to itself and the environment. The perception of outside stimulus or perturbations is essential to keep balance and prevent falls. However, there are some types of diseases that can cause impairments in the functioning of these [39].

Issues at the level of the peripheral vestibular system can cause dizziness [40]. Vestibular system problems are the most common issue that can cause disturbances in body balance, with almost 50% of these disturbances being cause by them [40] [41].

Regarding the visual system, it is known that the human body uses it to have the perception of the world around it. From visual images that arrive at the human eye, the brain uses this information to predict the shape, size, color and even if the object is moving or not. It that information, the human body can adjust his movement according to what is surrounding it [25][42].

There are two types of visual impairments that can affect our perception of what is around it: space agnosia and movement agnosia. Space agnosia occurs when the subject has difficulties recognizing a 3-dimensional shape. Movement agnosia occurs when the subject has difficulties seeing an object moving. The subject can tell that the object moved but could not see it move it. Both of these diseases cause impairments in understanding what is around it. Because of that, the response to a disturbance may not be the best applied [42].

Finally there is the somatosensory system. This system differs from the rest of the sensory systems. Receptors are not localized in just one part of the body. Instead, they are all over the human body. The information gathered by these receptors is divided into four different categories: temperature, touch, body position and pain. Two of these are especially important in postural control: body position and touch. The receptors can gather this type of information from skin, muscles, tendons, connective tissues of joints and in the walls of the internal organs [25].

In the absence of information from the receptors described above, movement is impaired. One type of disease that can cause loss of sensibility in the peripheral body extremities is peripheral neuropathies. Patients that suffer from this disease may not have sensibility in foot plantar zone [25]. Therefore patients have big difficulties in standing in an upright standing position with their feet together and their eyes closed, due to the fact that these patients do not have information about foot plantar zone when they close their eyes [25].

CNS is the bridge between the arrival of the outside stimulus at the sensor system and the muscular response of the motor system. The coordination between the three system described above, ensures that when the information arrives at CNS, this system can send the appropriate response to the motor system [42].

One example of a disease in CNS is multiple sclerosis (MS). MS is a chronic inflammatory demyelinating disease of the CNS and is characterized by the loss of myelin of the axons. By demyelinating, MS affects the ability of the brain cells and brainstem to communicate with each other. Therefore patients that suffer this condition can experience changes in the sensory system, muscular fatigue or muscular spasms, being more likely to have problems moving and controlling their posture [43].

The last step in the chain of maintaining postural control is motor response by the motor system. The musculoskeletal system is part of this system and has an important role in maintaining posture and balance. Lesions on the musculoskeletal structures can bring some perturbations in maintaining balance and posture [22][44].

Rheumatologic and orthopedic disorders can bring lesions on the musculoskeletal structures and therefore problems with balance. This type of disorders at lower limbs levels can be associated with arthrosis or ligament injuries at knee or ankle levels. Spinal disorders can also cause major complication in posture and balance. The musculature in the spinal zone has a crucial importance because these muscles have a double function: motor effector and sensory captor. Spinal complications normally it is accompanied with pain. Experiencing pain at the level of the spine can be an impairment in maintaining a correct body posture and consequently maintaining the center of mass within the limits of stability [22].

Regarding all the systems mentioned before, it cannot be considered that one of them is more important than another. All systems have their role in the postural control and damage in one of them can bring impairments in maintaining a correct posture and balance [42] [44].

2.2.4.1 Ankylosing Spondylitis

Rheumatologic Diseases are disorders characterized by inflammation that may appear in various tissues: joints, ligaments, bones and muscles and even some internal organs. Redness, swelling, and pain are characteristics that are present in the inflammatory tissues. These types of disorders can cause loss of function in the inflammatory tissues, that could lead to impairments in perform daily life activities and difficulties performing some movements [45].

When the spine is primarily affected it is called spondyloarthropathies [45]. Ankylosing spondylitis is a type of rheumatologic disease. This disorder is characterized by chronic inflammation in the spine area. Vertebrae of the spine fuse together, forming a rigid spine with little freedom of movement. Patients who suffer from this disorder present a kyphotic position. As a result, these patients present a poor posture and have impairments in maintaining balance [16] [46].

The loss of balance linked to this condition is caused due to the inflammatory process in the spine tissues (joint and muscles). This inflammation causes stiffness in the spine and that impairs the ability of the patients to balance themselves when there is a sudden change of posture [16].

2.3 Instruments used to analysis of postural control

2.3.1 EMG

Musculoskeletal structures have an important role in maintaining balance. Some authors consider that the first step in assessing postural control is to evaluate the motor system and all the musculoskeletal tissues that evolve it. Pain, restriction of joints range of motion, and muscle weakness can influence the human body equilibrium positions by restricting the necessary movements that are required to achieve balance [38].

Regarding muscle activation, this can be evaluated by a technique called EMG. EMG sensors can provide an indirect measure about muscle activation, and by that, it can be seen if there are some abnormalities in the muscles in evaluation [47].

In order to understand EMG signals, the basic comprehension of muscle activation and the way muscle generate bioelectric signals is needed. The human motor system has to coordinate outside and inside information in order to perform a diverse range of tasks such as regulate force outputs, maintaining an upright position, moving, and gesture [48].

To begin to understand how the motor system works, the smallest functional unit must be explained. The motor unit is defined as the conjugation between the cell body and dendrites of a motor neuron (alpha motor neuron), the axon and its multiple branches (synaptic innervation), and the muscle fibers innervated by those branches (see Figure 2.3). The alpha motor neuron is where the summation of all the inputs arrives. The activation of the fiber muscles is the last step of the chain of muscle activation. The number of motor units in the human muscle it may vary between 100 and 1000, dependent of the area of the muscle [48][49].

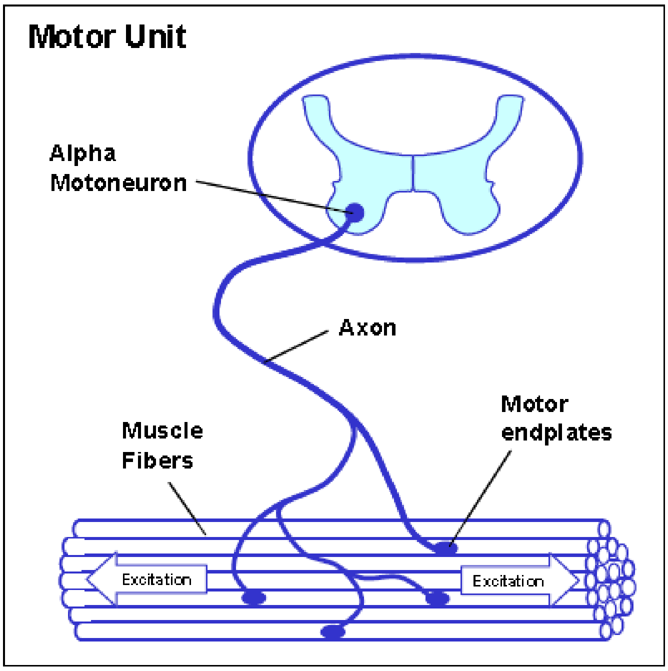

Figure 2.3 - Graphical representation of a motor unit (Adapted from [49]).

The ability a muscle has to contract or relaxed is explained by the semy-permeable membrane model. This model explains the permeability of the muscle fiber membranes have to certain ions such as sodium and potassium. When the muscle is relaxed, an ionic equilibrium between the inner and outer space of the muscle cell is maintained. This equilibrium is called resting potential of the muscle fiber membrane, and that is equivalent to a difference in potential of approximately of -80 to -90 mV [49]. This difference in potential is maintained by the ion pump and results in a negative intracellular charge compared to the outside of the cells. When a stimulus arrives, the cells of the muscle fibers are excited and the ion pump opens, letting sodium ions flow in. The diffusion characteristics of the muscle fiber membrane are briefly modified and a positive intracellular potential occurs. This process is called depolarization [49]. Briefly after, the membrane returns to the initial state by a process called repolarization (see Figure 2.4).

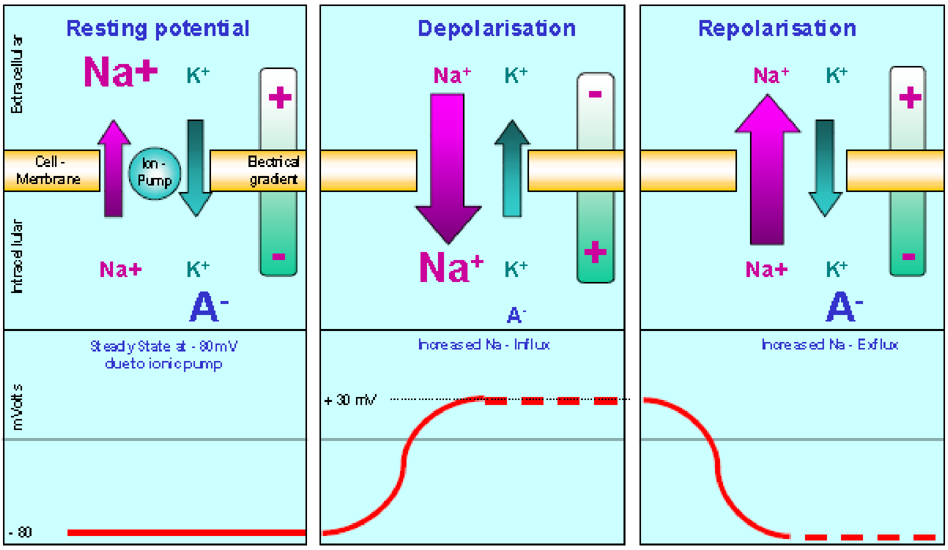

Figure 2.4 - Illustration of the depolarization and repolarization cycle within the excited muscle cells (Adapted from [49]).

The changes between ions in the muscle cell membrane create an electric signal called action potential (see Figure 2.5). The sum of the all action potential that occurs in a muscle is what it can be measured by the sensors of EMG (see Figure 2.6) [48][49].

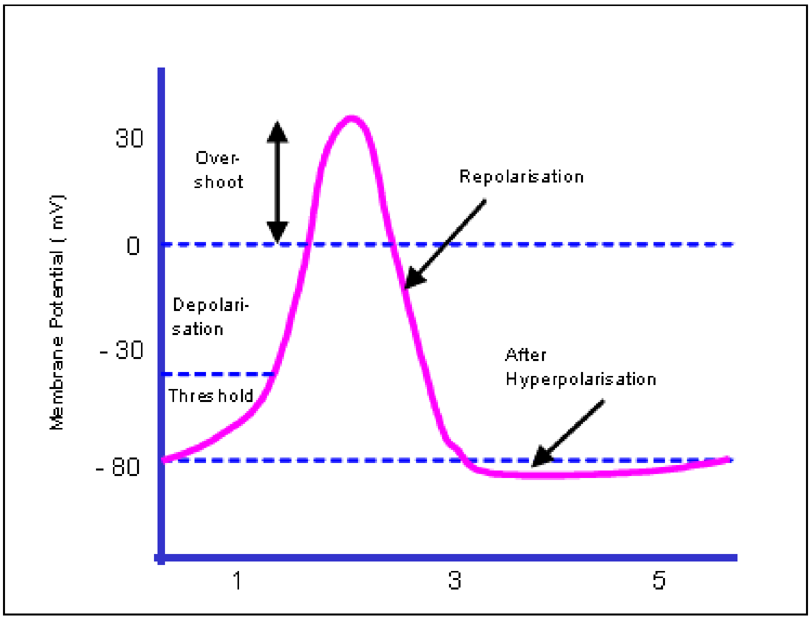

Figure 2.5 - Illustration of an action potential signal (Adapted from [49]).

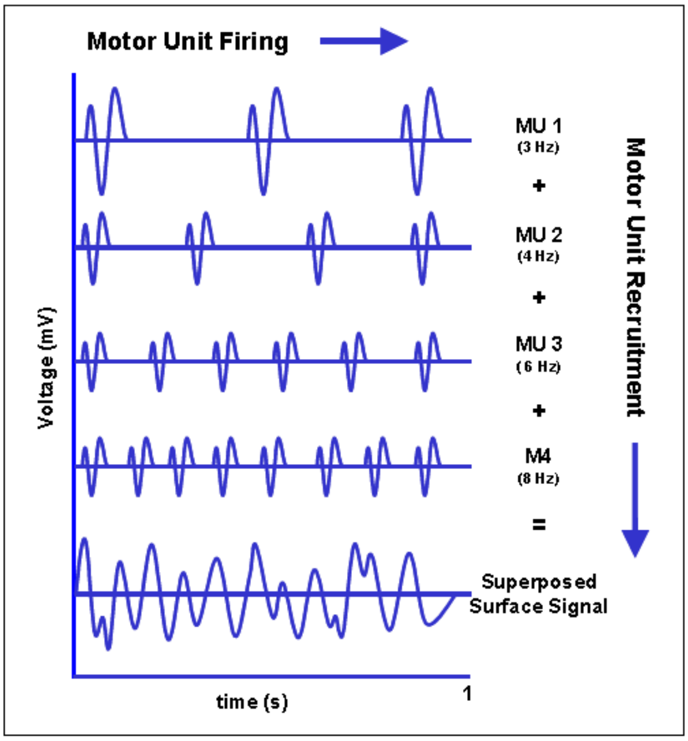

Figure 2.6 - Recruitment of the different motor units in a muscle and the resulting signal recorded by EMG surface sensors (Adapted from [49]).

EMG is a valuable technique used to measure electromyography potential through surface electrodes. The contraction of the striated muscles causes electrical stimuli to be released, which is detected on the surface of the skin by the superficial electrodes [50]. EMG is used in the scientific community for various purposes, such as rehabilitation, progress assessment, treatment planning, project research, among others [51].

The electromyographic signal is an extremely complex signal (see Figure 2.7), which can be affected by a number of reasons, such as anatomy and muscle physiology, electrode placement, and acquisition equipment, so it is important to correctly position the electrodes and correct handling of the instrumentation, in order to reduce the possibility of artifacts in the signal [49].

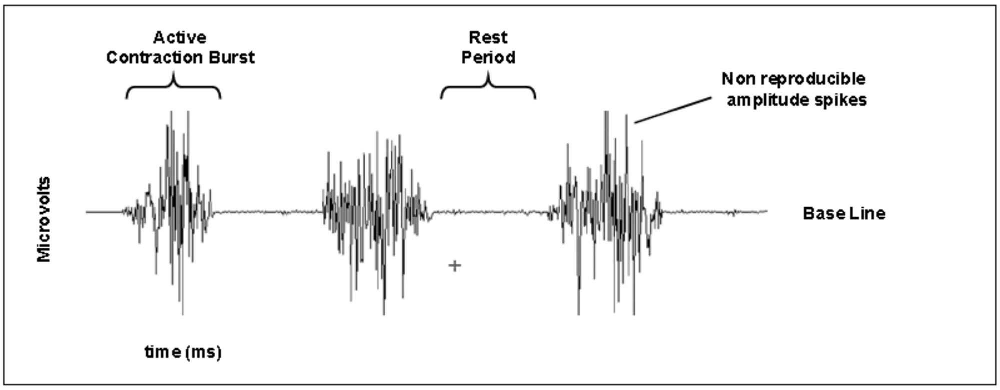

Figure 2.7 - Illustration of a raw EMG signal regarding 3 periods of time contraction (Adapted from [49]).

In the analysis of a set of electromyographic data, there are important parameters that can give us fundamental information about the functioning of the musculoskeletal system, or even about the correct use of the device/electrodes. These are peak-to-peak amplitude, mean amplitude, frequency, duration of activity, signal shape, phase, signal-to-noise ratio, time to reach peak value among others [49].

There are many factors impacting the EMG signal quality. Some of these factors will be discussed in the following sections.

Tissues Characteristics: In general, human body tissues are a good electrical conductor. However, this electrical conductivity can vary due to the type of tissue. Stiffness, thickness, and temperature are all factors that can influence the type of signal that EMG technique can capture. Fat tissue is a type of tissue that can negatively influence the ECG signal quality.. Fat tissue has a lower conductivity and therefore the signal that we capture has lower amplitude compared with a signal capture in a zone that does not have much fat tissue (see Figure 2.8) [49].

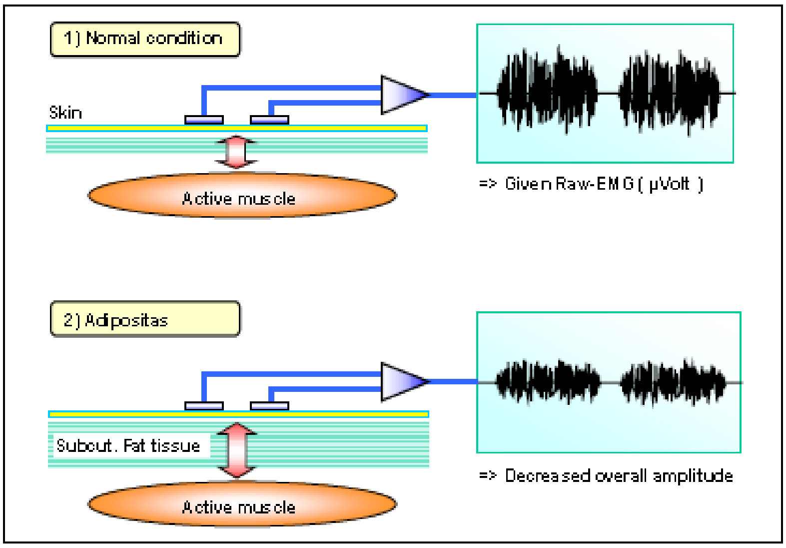

Figure 2.8 - Influence of thickness below the electrodes and the raw EMG signal in both cases (Adapted from [49]).

External noise: Nowadays, we are surrounded by electrical equipment, and some can influence the EMG signal. Especially when the ground electrode is not correctly placed, the surface electrodes can be more easily influenced by the signal of the others electrical equipment [49].

Electrodes: The quality or type of the electrodes can also influence the raw EMG signal. If the electrodes are always disconnecting, the signal is contaminated with others signals. Also, the incorrect placement of the electrodes can influence signal quality. If the electrodes are placed incorrectly, they can be properly checking another muscle or ever another physiologic signal. This can be minimized by check all the equipment before starting any acquisition [49].

Changes in the geometry of electrodes placement and muscle site: The distance of the electrode placement to the muscle that we are being evaluating can also influence the raw EMG signal. When the human body does any sort of dynamic movement the placement of the electrodes can change and the signal can be distorted [49].

2.3.2 Posturography

Posturography studies have been carried out since the 1970s, using force platforms to acquire the data and to assess postural control [2].

Posturography is a noninvasive method which use force platforms, to indirectly evaluates postural control. There are two types of posturography: dynamic posturography and static posturography. Dynamic posturography focuses on assessing the posture of an individual when he or she is in motion. In contrast, static posturography is characterized by the evaluation of postural control in positions that do not require much movement, such as standing position and sitting position [4]. This project focuses on static posturography.

COP is the most used parameter in posturography studies. This is defined as the representation of all dynamic done by the human body in order to maintained balance [2] [13]. The forces exerted on the platform summarize the set of forces that the individual exerts in order to control his posture.

COP measures can be divided in to two different directions: antero-posterior (sometimes designated as y direction) and medio-lateral (sometimes designated as x direction). Furthermore, COP measurements can be seen in two different forms: stabilogram and the stabilogram diffusion plot. The normal stabilogram is the representation of one of the direction of COP represented during a time series. Stabilogram diffusion plot is the map that represents the antero-posterior direction versus the medio-lateral direction (see Figure 2.9) [12].

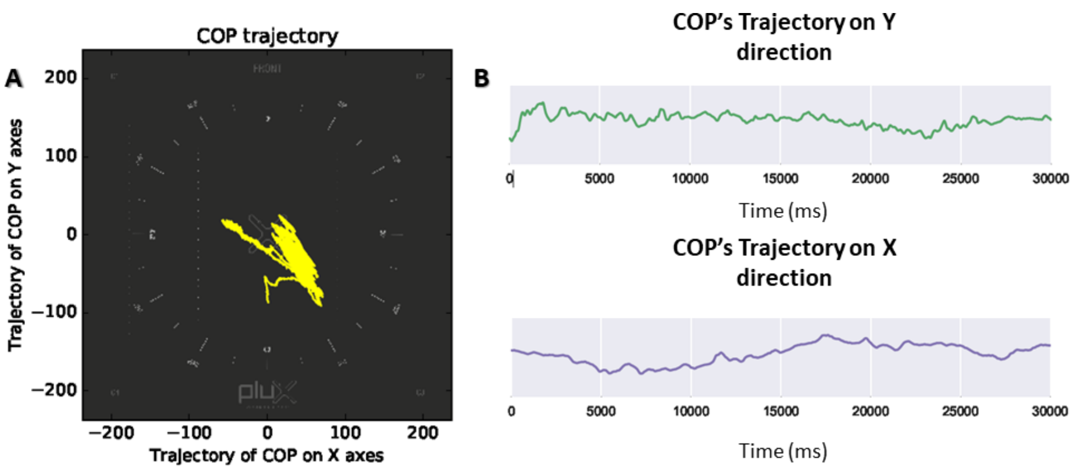

Figure 2.9 - Illustration of both representative ways to show COP measurements. (A) Diffuse Stabilogram and (B) Normal Stabilogram.

Through the COP analysis, there are numerous important measures for the assessment of postural control: the amplitude of the COP trajectory, the standard deviation of COP trajectory, the total area of COP trajectory, COP frequencies, and the velocity of the COP.

- **COP Amplitude:** The reach of the COP trajectory is a measure that is used to estimate the performance of the individual in the relation to posture control and balancing [12]. The amplitude of the displacement of the COP is defined by the difference between the maximum value and the minimum value of the trajectory. It is assumed that an individual who has a large reach on his or her COP trajectory has some difficulties in controlling his or her posture or needs to make some adjustments to maintain stability [2]. It is important to note that this parameter should be used in terms of comparison [9].
- **COP Velocity:** COP velocity is a measure that estimates the amount of activity spent on stability control. This parameter is defined as the total displacement of the COP within a certain period of time. This is a good indicator of postural control. The higher the COP speed, the greater the trajectory performed during the considered period of time, and the greater the difficulty in maintaining postural stability [2].
- **Standard Deviation of COP trajectory:** This is a measure that gives the dispersion of COP trajectory in comparison of the mean value of the trajectory. Evaluating this value along the COP array can give information about the adjustments of the human body during some type of destabilization [12].
- **Total area displacement**: Total area is the value that can give information about the total displacement of the COP trajectory. A bigger area is associated with bigger a need to adjustment movements in order to maintained balance [12].
- **COP Frequencies:** Analysis of the frequency spectrum is useful technique for measuring balance stability. Some studies suggest that each sensor system has a bigger contribution in a specific range of frequencies. However, the conclusions about this topic vary. Due to the fact that the power spectrum of frequencies has a range so small, a more exploratory analysis of this is done. Peak frequency, mean frequency, median frequency, and frequency at 80% of the power spectrum are analyzed. In literature, it is considered that the frequency at 80% of the power spectrum is the one that better represents the changes in balance and in postural control [12].

The COG, in the other hand, cannot be measured directly through the data acquired by the platform. COG and COP are directly related, and often can be confused [2].

Small changes in the COG cause changes in the COP. When there is an external stimulus to destabilize the balance, the COG can pass the stability limits, causing changes in the forces exerted on the platform. That said, it is to be expected that there will be a bigger displacement of COP when comparing with the COP displacement in an equilibrium position [2] [9].

Although COG and COP are very important parameters in the posturography study, COP is the most used because it is considered the most relevant for the study of postural control [2].

3

3. State of Art

In this chapter, the state of arte of both EMG and posturography will be presented. It is important to be aware of what has already been done in the past, so that the gaps in this type of studies can be fulfilled.

3.1 EMG Studies

EMG is a technique with a long history. In 1790, Galvani, managed to correlate two important topics in the EMG: muscle contraction and electricity. He discovered that contraction was possible through electric signals produced in the muscle [49]. However, it was only in 1800 that the first device that detected muscle activity was invented. After many years and much contradiction, in 1930 EMG began to be used in clinical studies, such as the diagnosis of muscular anomalies. Along the years, EMG has been gaining popularity, and nowadays it is used for several studies in the most diverse areas [49].

As mentioned in the introduction, muscle control and their proper functioning are two of the most important factors in postural control. However, there are not many studies with EMG at the trunk level. Most of the studies focused on lower limb EMG [18].

Nonetheless, the importance of EMG in assessing postural control and balance is recognized. In Ghasemzadeh et.al [47], a study is described in which the objective was to predict the risk falling of a group of subjects. It was concluded in this study that it was not possible to predict the risk of falls only with the COP parameters. It was necessary to resort to the EMG and to evaluate the musculoskeletal system.

O'Sullivan et.al [28], performed a study were the main goal was to verified the importance of the trunk muscle along different positions adopted by the human body. One of those positions was the upright standing position.

Regarding standing position with was concluded that the maintenance of standing position is achieved through the activation of the anterior abdominal musculature, more specific the activation of Rectus Abdominis [28]. In the same study, it was also concluded that the muscles inserted on the lower back, have little or none activation during quiet standing position [28].

One of the impairments of the study reported by the author was the lack of postural standardization within the aims of the study. Therefore, the author had some difficulties in the comparison of his study with others [28].

Although this study was not correlated with posturography tests, this had some interesting conclusion about standing positions and muscle activation of trunk muscles during the performance of this position.

3.2 Posturography Tests

Posturography is not a recent technique for postural analysis. Since the 1970s, force platforms have been used for the evaluation of postural control and balance [1], although this was not always the case. Prior to the existence of force platforms, health professionals assessed postural control and balance by performing observable or countable tasks, such as the length of time that an individual can sustain on one leg [5]. However, with the emergence of force platforms the assessment of postural control has become easier.

Traditionally, posturography tests include two essential conditions: double stance with visual feedback and double stance without visual feedback [22]. However, over the years, new tasks complementary to those previously described, have been implemented.These tests aim to replicate an everyday situation, causing some destabilization in order to perceive how the individual under study reacts.

Through the force platform the COP trajectory is measured, and analyzing this, it is possible to evaluate the postural control. For this, several protocols were developed, each depending of the aim of the study [52].

In Loughran et. al., [52] a simple protocol is described, with some tasks devise to represent some perturbations experienced in the daily life routine. This protocol presents 4 tasks:

1. Upright standing position, with arms along the body, and with visual feedback;
2. Upright standing position, with arms along the body, and without visual feedback;
3. Upright standing position, with arms along the body, and with visual feedback. Foam surface is included;
4. Upright standing position, with arms along the body, and without visual feedback. Foam surface is included.

The foam surface is placed on top of the platform (see Figure 3.1), so as to cause some destabilization in the postural control system. This test is a traditional test that was done even before the existence of force platforms, called "foam and dome". However, the force platform was used in order better analyze postural adjustment of the subjects in the study [52].

Figure 3.1 - Representation of the tasks that include foam surface (Adapted from [52]).

It is not only the protocols that have undergone changes. Also the platforms have been evolving, and with it, the possibility of a wide range of tests that previously would not be possible. In Chaudhry et.al, [9] a very different protocol as well as a very different platform is presented when compared to the previous ones. In this study, the NeuroCom Balance Master platform was used, and a protocol called Sensory Organization Test (SOT) was performed.

The device consists on a moving platform, a visual evolvement that also moves, and a harness to avoid unnecessary falls (see Figure 3.2) [9] [53]. The NeuroCom Balance Master device performs the evaluation of postural control. At the end of each task it is demonstrated on the computer screen the evaluation that the individual had in the accomplishment of that task [9].

The six tasks of the protocol are described as follow:

1. Visual feedback, fixed platform and fixed evolvement;
2. No visual feedback, fixed platform and fixed evolvement;
3. Visual feedback, fixed platform and moving evolvement;
4. Visual feedback, moving platform and fixed evolvement;
5. No visual feedback, fixed platform and moving evolvement;
6. No visual feedback, moving platform and fixed evolvement.

Figure 3.2 - Representation of NeuroCom Balance Master platform (Adapted from [53]).

It is important to understand that posturography tests are performed with the main goal of causing some unexpected destabilization that may cause some disequilibrium in human body. Causing this destabilization, the examiner can perceive if there are any impairments regarding postural control and posture.

Impairments in postural control system can be caused due to different reasons. One of those reasons is impairments in visual feedback.

Agostini et. al [14], studied the influence of central vision in postural control assessment. Posture during target fixation and while their eyes were closed was evaluated. This author concluded that subjects swayed more under eyes closed conditions, when compared to eyes-open conditions. However, study conducted by Bugnarariu [54] said that if the standing surface is fixed, and any disturbance is inflicted, the conditions eyes-closed and eyes-open do not have significant differences. In this situation, the somatosensory has a bigger contribution, when comparing to visual system.

Also in Bugnarariu [54], the contribution of aging was studied. In these study 10 young subjects participated with a mean age of 26 years old ± 5,1 years old, and an older sample with a mean age of 72 years old ± 3,3 years old also participated.

The results showed a prefund influence of aging regarding postural control system. Older subjects presented a bigger variation in COP displacement, when compared to younger subjects, and also a bigger difficulty to recovering from an outside stimulus, especially in the presence of sensory conflicts [54].

Taylor et. al [10], also performed a posturography test where the main goal was to verified if talking, time before data acquisition, and visual fixation had some influence in postural assessment. Young and older samples were evaluated during the study.

The results of this study were inconclusive. It was concluded that the results had inconsistencies in posturagraphy tests, where the methods used could affect the results obtained on the study. This author also concluded that to avoid this inconclusive studies, a standardized posturography testing method should be developed to limit these inconsistencies [10].

4

4. Methods and Materials

This chapter has as main goals to make a brief introduction of the equipment used in the study, the protocol constructed for the study as well as the entire analysis procedure used to analyze the signals recorded.

4.1 Questioner/Equipment

Before any acquisition, the subjects in the study were asked to fill a questioner. The main goal of the questioner was to gather information about the subjects that may have an important contribution in postural control and this way characterized the sample. The information gathered is as follow:

- Socio-demographic characteristics: nationality, profession, educational qualifications, marital status, and gender;
- Biomechanical characteristics: age, height, and weight;
- Dominant hand.

This questioner can be consulted in appendix A.

Regarding acquisition equipment, two main equipments were used: a force platform and an EMG acquisition system.

Displacements of the COP were recorded using a force platform from Plux (Plux Wireless Biosignals S.A., Portugal) (see Figure 4.1 a)). This force platform is constituted by 4 steel load cells and can carry a load up to 800kg (200kg per cell), sending data over bluetooth up to a sampling frequency of 1000Hz and a resolution of 16 bits.

EMG signals were recorded using the biosignals research kit from PLUX with 8 channels (see Figure 4.1 b)). The acquisition module in this kit is a biosignalPlux has 8 analog channels with a resolution of 16 bits. The data is sent wirelessly using bluetooth and with a sampling frequency up to 1000Hz.

a) b)

Figure 4.1 - Aquisition Equipment. a) Force platform and b) Biosignals researche apparatus (Adapted from [55]).

The sensors used were 8 emgPLUX, a EMG sensor from Plux. To connect the sensors to the patient, 2 Ag/AgCL with solid adhesive pregelled electrodes were used per sensor (TIGA-MED Gold 01-7500, TIGA-MED GMBH, Germany).

All signals recorded using Plux's OpenSignals and were stored in H5 files and processed offline using Python.

4.2 Protocol

Before proceeding to data acquisition, subjects were asked to fill the characterization questionnaire.

Multichannel EMG recording were recorded from four different muscles on both medial planes (left and right) throughout the protocol. These muscles are as followed: rectus abdominis (around 3 cm lateral to the midline above the umbilicus), external obliques (around 10 cm lateral to the midline above umbilicus and aligned with muscle fibers), iliocostalis (around 6 cm lateral to the midline at the L3) and multifidus (around 2 cm lateral to the midline at the L5) (see Figure 4.2) [56]. A ground electrode was also used in the pisiform bone, in order to prevent electric noise from interfering with the EMG signal.

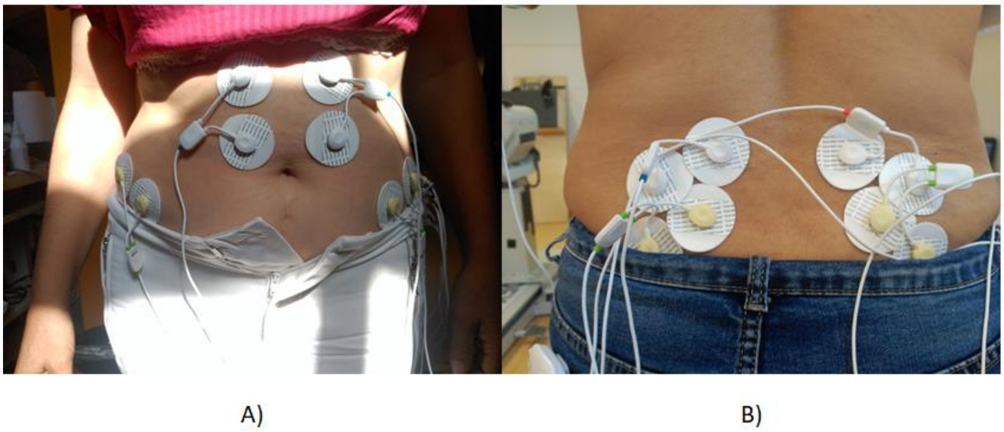

Figure 4.2 - Illustration of the placement of the electrodes. A) placement of the electrodes in the abdominal wall and B) placement of the electrodes in the lower back.

Subjects lay down on a marquise for 15 seconds in a supine position in order to record a baseline for the muscle activity. Maximum voluntary contractions (MVC's) tests are then performed on the muscles previous described. For testing the MVC of rectus abdominis, the subjects lay down on a marquise in a supine position with their hands clasped behind head. The examiner stands beside the subject's marquise and stabilizes the pelvis by leaning across the patient with the forearms. At the same time, while the subjects were doing upright force, the examiner counters the movement by placing his hand on the subject's chest [57]. For the external obliques MVC's, the subjects lift their upper body and rotate to one side, while the examiner counters the movement by placing his hand on the lifted elbow [57]. This task is done for both sides. The subjects then turn to a prone position. With their hands clasped behind the head, subjects do upright force and lift their upper bodies. The examiner places his arm across the pelvis to stabilize it and places the other hand between subject's shoulders to counter the movement [57]. These tasks were performed three times.

Derived from previous studies, nine tasks were selected to be performed in the platform. Regarding task 1 to 6, these tasks have either 30 seconds duration or as long as it could be managed. Regarding tasks 7, 8, and 9, the time that takes to complete it varies. Below is a description of all 9 tasks:

1. Subjects stood on the force platform in an upright position with their hands hanging along the body, with visual feedback (eyes open) [2][28][41];

2. Subjects stood on the platform in an upright position with their hands hanging along the body, with no visual feedback (eyes closed) [2][28][41];
3. Subjects stood with only the right foot on the ground, with visual feedback[2][22];
4. The step 3 but without visual feedback [2][22];
5. Subjects stood with only the left foot on the ground, with visual feedback [2][22];
6. The step 5 but without visual feedback [2][22];
7. On a table, an object is placed on the left side of the subjects, at a distance of 15 cm beyond the length of their extended arm. It was asked to subjects to reach the object with their right hand[58][59][60];
8. The same object was placed on the right side of the subjects at the same distance that before and it was asked for the subjects to reach the object with their left hand [58][59][60];
9. According to the dominant hand of the subject, an object was placed in the direction of his dominant hand at the same distance as before. Then it was asked for the subjects to reach the object with their dominant hand [58][69][60];

The study was conducted at FCT-UNL and at CEDOC. The experimental protocol was approved by the Centro Hospitalar Lisboa Ocidental ethical committee and all participants gave their written informed consent to participate in the study. The written informed consent can be consulted in appendix B.

4.3 Data Processing

All signals were sampled at 1000 Hz (platform signals and EMG signals) and with a 16 bit resolution. Platform and EMG signals were recorded at the same time to prevent any desynchronization.

Signal treatment and data analysis were performed using Python programming language, using numpy toolbox (version - 1.10.4), scipy toolbox (version - 0.17.0) in the python language (version python – 3.3).

EMG signals were averaged out and then the root mean square formula was used to get the signal envelope. The window used was 100 samples (1 sample is equivalent to 1ms) [49][61]. Each muscle RMS signal was then normalized using the maximum value of the respective MVC. After the envelope was normalized, peak value, mean value, and median value were calculated for each EMG array. Using the formulas from the datasheet (see appendix C), platform signals underwent a pre-processing phase where the raw signal was converted to a COP displacement in the antero-posterior (AP) direction (Y direction) and medio-lateral (ML) direction (X direction). Then for each direction, the signal was averaged out. The mean velocity, standard deviation, and amplitude of the signal of each direction were calculated. Area of the total COP displacement was also calculated, using the convex hull algorithm and the Green's theorem.

Fourier analysis was done for EMG data and COP data, using the periodogram function from scipy. Peak frequency, mean frequency, median frequency, and frequency at 80% of the power spectrum were calculated.

After all analysis of the signals, the results were saved in an Excel file using xlsxwriter (version - 0.8.4) and openpyxl (version - 2.3.2) python toolboxes.

All plots were constructed using Python programming language using matplotlib.pylab toolbox (version - 1.10.4).

4.4 Algorithms in Data Processing

In this section some algorithms used during the realization of the study will be explained.

4.4.1 Root Mean Square (RMS) Algorithm

This operation is based on the square root calculation and it is the most recommend function for smoothing the signal. The RMS creates an envelope that involves the raw signal (see Figure 4.3), by using a moving window that calculates the square root of the data that is inside the window. It is considered that this formula provides an insight on the amplitude of the signal producing a waveform easily to analyze. [49][61].

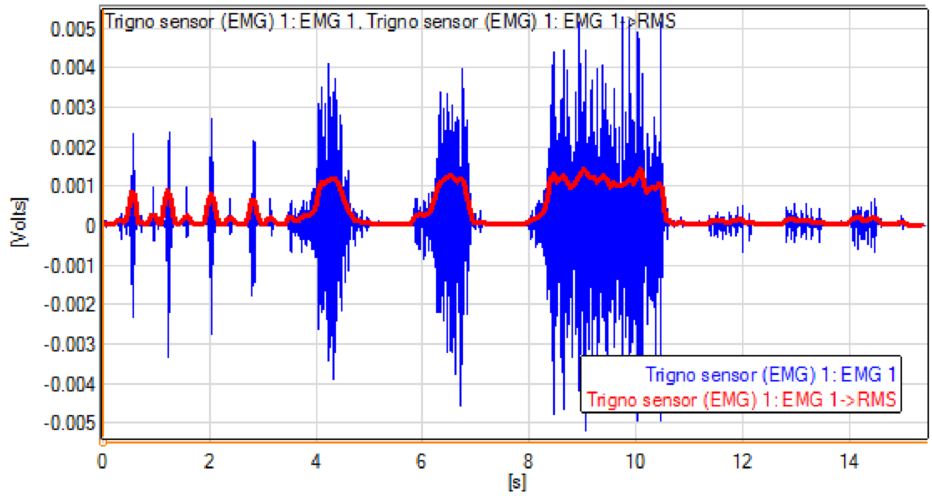

Figure 4.3 - Illustration of a raw EMG signal (blue signal) and after applying the RMS algorithm (red signal) (Adapted from [61]).

RMS is obtained using Formula 4.1 [61]:

$$RMS = \left(\frac{1}{S}\sum_{1}^{S} f^{2}(s)\right)^{\frac{1}{2}} \quad (4.1)$$

, where s is de length of the window (points) and f the signal.

The window length is an important factor when EMG amplitude varies. Fast movements and slow movements should have different length windows. Fast movements transcribe rapid changes in signal amplitude, so a small window length should be used. When EMG amplitude is slowly varying, longer window length should be used. However a window between 50ms to 100ms it is recommended for both cases [49][61].

The length of the window has also a very important role in signal-to-noise ratio. The higher this ratio is, the less noise the signal has. St-Amant et.al [61] studied the relation between window length and signal-to-noise ratio. This author proved that the bigger the window length is, the bigger is the signal-to-noise ratio. However, if the purpose of the study is to evaluate the EMG amplitude, a smaller window length should be used, since a bigger window length is produces a lower amplitude of the signal.

4.4.2 Maximum Voluntary Contraction (MVC)

One of the biggest difficulties in EMG analysis is that amplitudes of EMG signal are strongly influenced by a big variety of factors. Signals can also vary between subjects due to each subject's anatomy and physiology. These factors are a problem when the purpose of the study is comparing EMG signals from different subjects. One solution to that problem is the normalization of the signals using MVC [49].

MVC normalization is a popular method that is performed before the tests trials. Normally this test is done by contracting the muscle in evaluation against a resistance force. That way it can ensure that the maximum force that a subject can do in that muscle is performed.

After having the MVC values, the test trials are normalized using the MVC value. That normalization is done by dividing the test trial signal by the MVC value, with MVC value is considered the maximum force of that muscle (100%) and the values of the test trials a percentage of the MVC value (see Figure 4.4) [49].

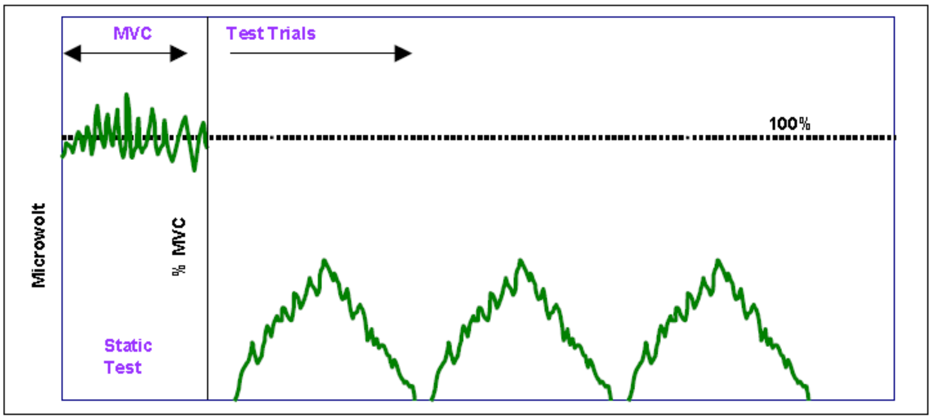

Figure 4.4 - Graphical demonstration of how the MVC normalization works (Adapted from [49]).

Although this type of normalization is often used in EMG analysis, this also has some drawbacks, more often in subjects with pathology or subjects with a high level of physical activity. Also, the MVC value may not be the maxi-mum value that the subject could reach, and the normalization of test trials could be pass the 100% [49].

4.4.3 Algorithms used for total area displacement of COP signals

For calculate total area displacement, some algorithms are needed. The convex hull algorithm is one algorithm that can be used for that purpose. Convex hull algorithm main goal is to find the smaller polygon that a finite set of two-dimensional points construct [62]. After this polygon is find, the Green Theorem is used to calculate the area value. Green Theorem is used when the curve is a closed curve in a two-dimensional space. This performs a double integral in the region of interest, and in that way provides the area value that the region occupies in a two-dimensional space [63].

5

5. Results

In this chapter the most important results of the study will be presented, in the follow order: brief description of the statistical treatment used, a brief description of the subjects that participated on the study, the analysis of the EMG and COP parameters for a group of healthy subjects and the relationship between each parameter and biomechanical variables, and at last the biggest changes between the healthy subjects (sample of control) and subjects with AS.

To understand this part of the document it is important to take into consideration some important informations. First of all, to simplify, the following acronyms for the tasks are used:

- SEO = Standing with eyes open;
- SEC = Standing with eyes close;
- RFEO = One leg stand, right leg and eyes open;
- RFEC = One leg stand, right leg and eyes close;
- LFEO = One leg stand, left leg and eyes open;
- LFEC = One leg stand, left leg and eyes close;
- RR = Reaching an object on the right side of the subject with his left hand;
- RL = Reaching an object on the left side of the subject with his right hand;
- RC = Reaching an object in front of the subject dominant hand.

Follow is the description of muscle's acronyms:

- ReR = Rectus Abdominis Right;
- ReL = Rectus Abdominis Left;
- OR = External Obliques Right;
- OL = External Obliques Left;
- IR = Iliocostalis Right;
- IL = Iliocostalis Left;
- MR = Multifidus Right;
- ML= Multifidus Left.

5.1 Statistical Treatment

The main goal of the study is to define a normal posture of a group of individual without any rheumatologic pathology. For that purpose, it was considered that the most important parameters are the mean and peak values and the frequencies of EMG data, and total area, mean velocity, amplitude, standard deviation, and frequencies of COP data.

For the analysis of the upright standing position the follow types of analysis were used:

- **Spearman Correlation Coefficient (*ρ*):** this statistical test allows calculation of the statistical correlation between two parameters. The correlation coefficient (ρ) various between -1 and 1. If this value is negative and near to -1 that means that the parameters have a strong correlation between them, however in opposite directions (indirect relation). If the value is positive and close to 1, the parameters have a strong correlation between them and various in the same direction (direct relation). This coefficient value is not sensitive to asymmetric distributions and heterogeny of the data [64]. This test was used to calculate the correlation value between each muscle in the same task, to calculate the correlation between each task in the same muscle, and for compare the relationship between BMI and age with the COP and EMG parameters for a group of healthy subjects.
- **Wilcoxon test:** Wilcoxon test is a non-parametric test to compared two paired groups of values. This test was used to compare different tasks in the same parameter, for a group of healthy subjects. This test has as a null hypothesis that is the median difference between the two set of values is zero [64];

- **Mann Whitney test**: The Mann Whitney statistical test was used to compare two unpaired groups of values. This statistical test is a non-parametric test that compares to set of values without normal distribution. This test was used to compare the group of healthy subjects with the group of pathologic subjects. The null hypothesis assumes that both set of values have similar distributions [64].

Boxplot graphics were used to the analysis of EMG and COP parameters. This type of graphic representation is used to representing the median value, the inter-quartile dispersion, and the maximum and minimum observations of a set of values. Values that were 1,5 times superior to the interquartile range were considered outliers. That means that those values could be an error measure [64].

All the statistical analysis was done on Python (version python – 3.3) and a p-value of 0,05 was considered to accept strong correlation.

5.2 Characterization of the sample - Healthy Subjects

EMG and posturography tests were performed in a sample of subjects without pathology (healthy). The characterization of the group of subjects was done according to the questioner in appendix A (see Table 5-1).

Table 5-1 - Table representing the characterization of healthy subjects group.

Sex	Age	Weight (kg)	Height (m)	Total Number of subjects	Condition
Female	**Mean:** 25,4 years **Range:** 18 – 53 years **Standard Deviation:** 9,1 years	**Mean:** 60,3 kg **Range:** 46 – 90 kg **Standard Deviation:** 10,6 kg	**Mean:** 1,63 m **Range:** 1,53 – 1,80 m **Standard Deviation:** 0,07 m	25	Healthy

Male	**Mean:** 25,0 years **Range:** 18 – 34 years **Standard Deviation:** 4,6 years	**Mean:** 72,1 kg **Range:** 57 – 88 kg **Standard Deviation:** 9,1 kg	**Mean:** 1,75 m **Range:** 1,67 – 1,90 m **Standard Deviation:** 0,07 m	14	Healthy

5.3 Analysis of posture parameters – Healthy Subjects

In this subchapter, the main results regarding the definition of posture for a group of healthy subjects is done throughout the analysis of EMG data and posturography data.

5.3.1 EMG data Results

During data acquisition, some difficulties were encounter. The electrodes sometimes disconnected causing some interference in raw EMG signals, and this could create some unexpected peaks. The most obvious outliers were not taking into account in the follow analysis. Since the maximum value could not be relied on, this was not considered important. That said, the mean of each EMG array was calculated and it was consider a more reliable parameter for EMG data.

5.3.1.1 Analysis of the Mean Value of the EMG arrays

For each EMG array, the mean value was calculated. It was necessary to verified if the mean value of each muscle EMG was correlated along each task. For that purpose the Spearman correlation coefficient (ρ) was used. Table 5-2 and table 5-3 show the spearman correlation coefficient between each task for right Rectus Abdominis and for left Rectus Abdominis respectively. In appendix D, the Spearman correlation coefficient for the other muscles between each task, can be consulted.

Table 5-2 - Spearman correlation coefficient of right Rectus Abdominis between each task. **p-value < 0,05.

		Right Rectus Abdominis								
		SEO	**SEC**	**RFEO**	**RFEC**	**LFEO**	**LFEO**	**RR**	**RL**	**RC**
	SEO	1	-	-	-	-	-	-	-	-
	SEC	0,96**	1	-	-	-	-	-	-	-
	RFEO	0,92**	0,96**	1	-	-	-	-	-	-
	RFEC	0,84**	0,88**	0,93**	1	-	-	-	-	-
(ρ)	**LFEO**	0,82**	0,89**	0,90**	0,92**	1	-	-	-	-
	LFEC	0,78**	0,87**	0,89**	0,89**	0,95**	1	-	-	-
	RR	0,93**	0,95**	0,93**	0,86**	0,86**	0,83**	1	-	-
	RL	0,87**	0,92**	0,89**	0,84**	0,88**	0,85**	0,94**	1	-
	RC	0,93**	0,91**	0,90**	0,82**	0,79**	0,73**	0,94**	0,87**	1

Table 5-3 - Spearman correlation coefficient of left Rectus Abdominis between each task. **p-value < 0,05.

		Left Rectus Abdominis								
		SEO	**SEC**	**RFEO**	**RFEC**	**LFEO**	**LFEO**	**RR**	**RL**	**RC**
	SEO	1	-	-	-	-	-	-	-	-
	SEC	0,98**	1	-	-	-	-	-	-	-
	RFEO	0,91**	0,94**	1	-	-	-	-	-	-
	RFEC	0,75**	0,76**	0,86**	1	-	-	-	-	-
(ρ)	**LFEO**	0,78**	0,78**	0,86**	0,80**	1	-	-	-	-
	LFEC	0,79**	0,79**	0,88**	0,78**	0,93**	1	-	-	-
	RR	0,85**	0,88**	0,82**	0,72**	0,76**	0,74**	1	-	-
	RL	0,87**	0,88**	0,81**	0,75**	0,82**	0,78**	0,92**	1	-
	RC	0,84**	0,88**	0,84**	0,77**	0,81**	0,78**	0,94**	0,96**	1

*** SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

As it can be seen on the tables, the spearman correlation coefficients are always positive and with values very close to 1. That means that the correlation between each task in right and left Rectus Abdominis is very strong and the positive signal means that the tasks have a direct relation (when increase in one task it also increase in the other).

Regarding the analysis of spearman correlation between each muscle in the same task, some interesting results were also observed (see appendix E). Table 5-4 and 5-5 show the spearman correlation coefficient in SEO* and SEC*, between all muscles.

Table 5-4 - Spearman correlation coefficient of the task SEO between each muscle. **p-value < 0,05.

SEO									
		ReL	**ReR**	**OL**	**OR**	**IL**	**IR**	**ML**	**MR**
(ρ)	**ReL**	1	-	-	-	-	-	-	-
	ReR	0,71**	1	-	-	-	-	-	-
	OL	0,49**	0,36**	1	-	-	-	-	-
	OR	0,38**	0,27	0,73**	1	-	-	-	-
	IL	0,11	0,23	0,20	0,15	1	-	-	-
	IR	0,16	0,18	0,25	0,12	0,80**	1	-	-
	ML	0,15	0,21	0,13	0,07	0,58**	0,67**	1	
	MR	0,33**	0,24	0,32**	0,17	0,54**	0,52**	0,61**	1

Table 5-5 - Spearman correlation coefficient of the task SEC between each muscle. **p-value < 0,05.

SEC									
		ReL	**ReR**	**OL**	**OR**	**IL**	**IR**	**ML**	**MR**
(ρ)	**ReL**	1	-	-	-	-	-	-	-
	ReR	0,70**	1	-	-	-	-	-	-
	OL	0,50**	0,40*	1	-	-	-	-	-
	OR	0,31	0,23	0,71**	1	-	-	-	-
	IL	0,20	0,33*	0,16	0,14	1	-	-	-
	IR	0,15	0,25	0,16	0,05	0,79**	1	-	-
	ML	0,16	0,28	0,13	0,06	0,52	0,60**	1	
	MR	0,36*	0,37*	0,26	0,11	0,47	0,45	0,56**	1

*** SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Both in the SEO* task and in the SEC* tasks it can be verified a significant correlation ($\rho > 0,70$ and $p < 0,05$) between the same muscle on both sides (positive correlation between left and right side in the same muscle). Although the Multifidus muscle do not have a correlation coefficient greater than 0,70 , this is statistical relevant and have a high correlation coefficient ($\rho = 0,61$ in SEO*, and $\rho = 0,56$ in SEC*).

5.3.1.2 Analysis of the frequencies of EMG

Regarding EMG frequencies, some interesting observations were noticed.

In the same muscles, each task was compared to all others, regarding the same frequency (peak frequency, mean frequency, median frequency and frequency at 80% of power spectrum). The Wilcoxon test was used to detect significant differences between the tasks in the conditions described before, and boxplot representation to observe the dispersion of data (see appendix F).

It was observed that the muscles that have less significant changes between tasks ($p > 0,05$) are the Rectus Abodminis muscles (ReR and ReL). This statement is true for all frequencies in analysis. Through boxplot analysis it was also noticed that this muscle has, in general, a similar dispersion throughout the tasks. Also, through this representation, it can be seen that there are not major differences between mean and median values of the set of values, along the nine tasks. This statement is true for all the frequencies in analysis.

Figure 5.1 represents the boxplot representations throughout the nine tasks for peak frequency in left Rectus Abdominis (ReL).

*** SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

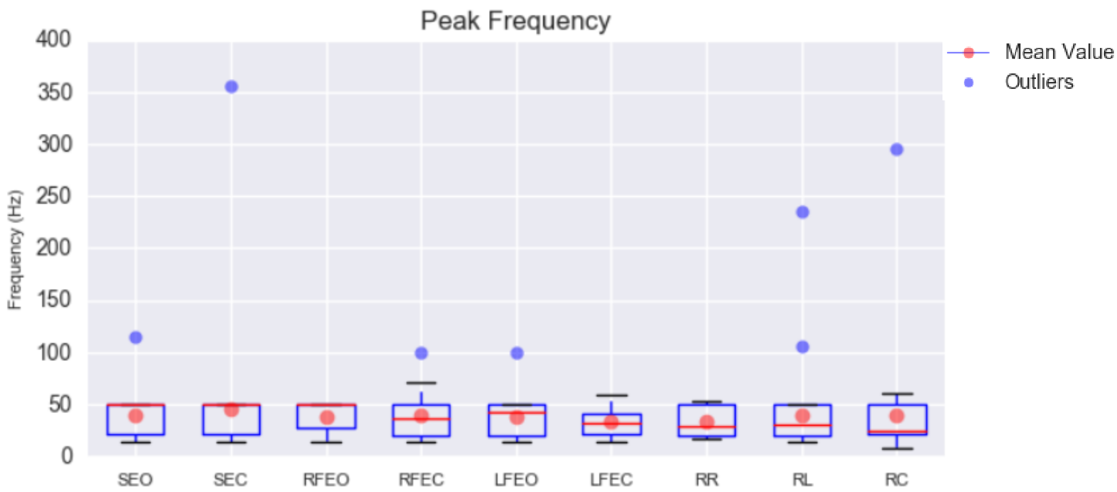

Figure 5.1 – Rectus Abdominis Left. Boxplot representation of peak frequency values along all nine tasks(N=39).

Regarding the muscles inserted on the lower back, it was noticed that there were some interesting results, especially regarding mean frequency. In this range of frequency, it was noticed that Iliocostalis as well as Multifidus, present a lower mean and median value of frequency in RFEC* and LFEC*, when compared with the same task with visual feedback (RFEO* and LFEC*).

For instance, in right Iliocostalis, the mean value of mean frequency in RFEC* decrease 23,6Hz and median value decrease about 28,4Hz, when compared to RFEO*. In LFEC*, mean value decreased about 28,4Hz and median about 22,3Hz, when compared to LFEO*.

For each frequency range in each muscle, each task was compared with the rest position EMG. Significant differences can be seen between each task and rest position, in all muscles and all frequencies ranges. Figure 5.2 represents the boxplot representation for each task, including rest position (REST), for left Multifidus for all frequencies range.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

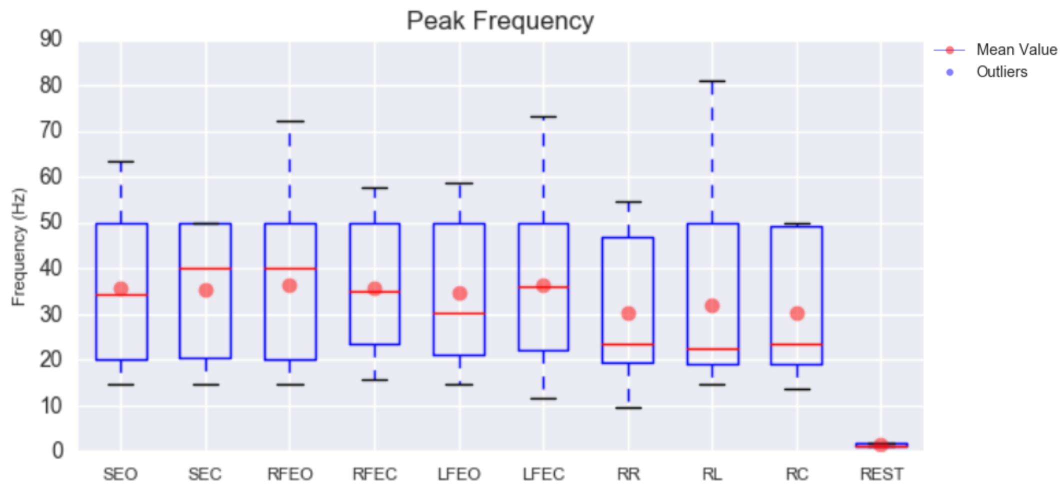

Figure 5.2 - Boxplot representation of left Rectus Abdominis (RL) trough out all tasks, including REST, regarding peak frequency (N=39).

5.3.2 COP Analysis

5.3.2.1 Analysis of COP amplitude

COP amplitude is a normal parameter calculated in posturography tests. This parameter was analyzed in both directions along the nine tasks (see appendix G).

In order to evaluate how the amplitude of COP behave in both direction along the performance of the nine tasks, mean values, standard deviation, median values were calculated for all the nine tasks in both directions for a group of healthy people (N=39). It was also important to verify the distribution of data in each task to have a more precise analysis. For that purpose boxplot graphs were used. The Wilcoxon test was used to identify the significant changes between the tasks and a p-value of 0,05 was used. Figure 5.3 and 5.4 represent the boxplot representation for both directions and for all nine tasks.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

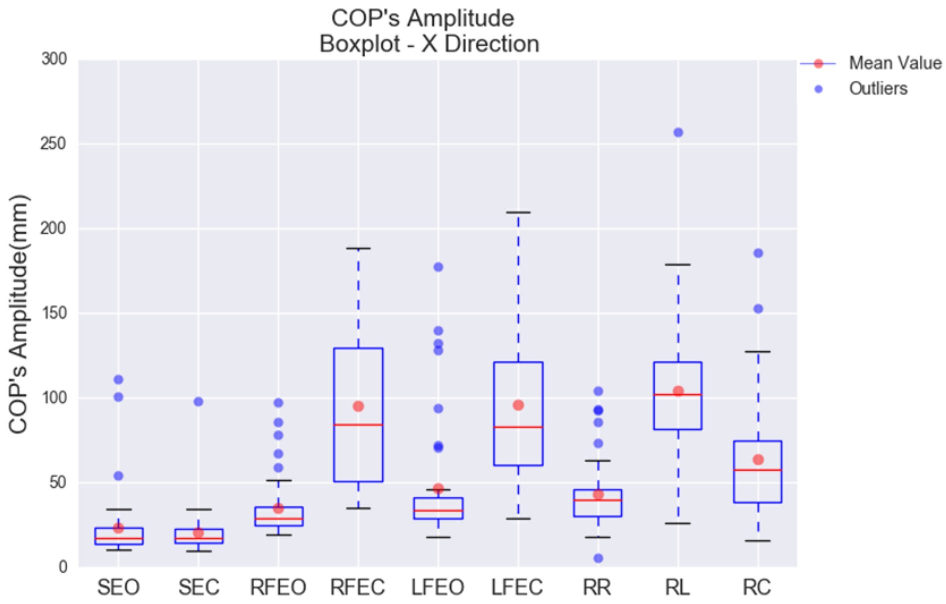

Figure 5.3 - Boxplot representation of COP's amplitude values for x direction, in each task (N=39).

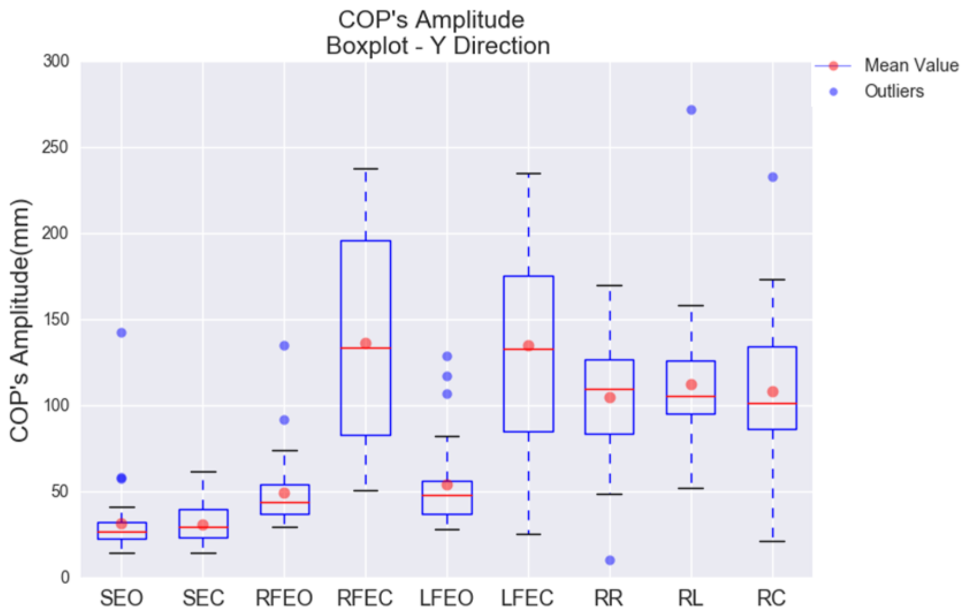

Figure 5.4 - Boxplot representation of COP's amplitude values for x direction, in each task (N=39).

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*SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.

After an overall analysis of boxplot graphics, differences between tasks and between directions were discovered.

When compared with x direction, y direction presents bigger mean values and bigger dispersion of values overall. It was also verified that y direction has a lower number of outliers when compared to the x direction. However, both directions have a similar behavior for the same task.

Regarding COP's amplitude in both directions the following observations were done:

- Regarding x directions, all tasks are statically different from each other ($p<0,05$) with the exception of the following pairs: SEO*/SEC*, RFEC*/LFEC*, RFEO*/RR*, RFEC*/RL*, LFEO*/RR*, and LFEC*/RL*;
- Regarding y directions, all tasks are statically different from each other ($p<0,05$), but also with a few combinations exceptions: SEO*/SEC*, RFEO*/LFEO*, RFEC*/LFEC*, RR*/RL*, RR*/RC*, RL*/RC*;
- The tasks that present the greatest differences when compared to all others are RFEC* and LFEC*. These tasks, in general, have larger data dispersion (large size boxplots), a larger mean value and median value, and a larger confidence interval at 95% (CI 95%);
- The tasks that with the lowest dispersion of data (small size boxplot), the lowest mean, median and CI 95% values are SEO* and SEC*;
- In the tasks where the subjects are supported only by one leg, it can be observed some obvious differences between those tasks where the existence of visual perception is present and where it is not. The absence of visual perception creates a greater dispersion of data, and higher values for the mean, median, and CI 95%.

In the following table (Table 5-6) is represented the mean values, standard deviation, median values, and CI 95% for the tasks that were considered more relevant in both directions.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Table 5-6 - Mean values, standard deviation, median, and range of boxplot (lower and upper limits) values for SEO*, SEC*, RFEO*, RFEC*, LFEO*, and LFEC*, for COP amplitude in x and y direction.

	X Direction			Y Direction		
Task	**Mean Value ± σ(mm)**	**Median Value (mm)**	**CI 95% (mm)**	**Mean Value ± σ(mm)**	**Median Value (mm)**	**CI 95% (mm)**
SEO	23,4 ± 20,7	17,4	10,2 – 34,2	31,3 ± 20,3	27,2	14,4 – 41,0
SEC	20,3 ± 13,9	17,4	9,7 – 30,0	30,8 ± 9,9	29,8	14,1 – 61,9
RFEO	35,4 ± 18,0	28,9	19,5 – 51,6	49,6 ± 19,2	43,8	29,5 – 73,7
RFEC	95,2 ± 46,2	84,2	35,1 – 187,9	136,5 ± 57,6	133,6	50,6 – 237,3
LFEO	46,9 ± 36,5	33,9	17,9 – 46,0	54,2 ± 23,2	48,2	28,0 – 82,4
LFEC	96,0 ± 45,7	83,1	28,7 – 209,7	135,2 ± 55,6	132,8	24,4 – 234,4

5.3.2.2 Analysis of Standard Deviation of COP signals

The standard deviation was calculated for both directions, for each task in each healthy subject (see appendix G).

For the analysis of standard deviation of COP signals in both directions, a similar analysis to COP's amplitude was done. Boxplot graphics were done, as well as the calculation of some important values of the most relevant tasks. Wilcoxon test was used to verify if, between tasks, significant changes are observed.

Through the analysis of boxplot graphics some significant differences can be seen between x and y directions, as well as between each task, regarding this postural control parameter (see Figure 5.5 and 5.6).

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

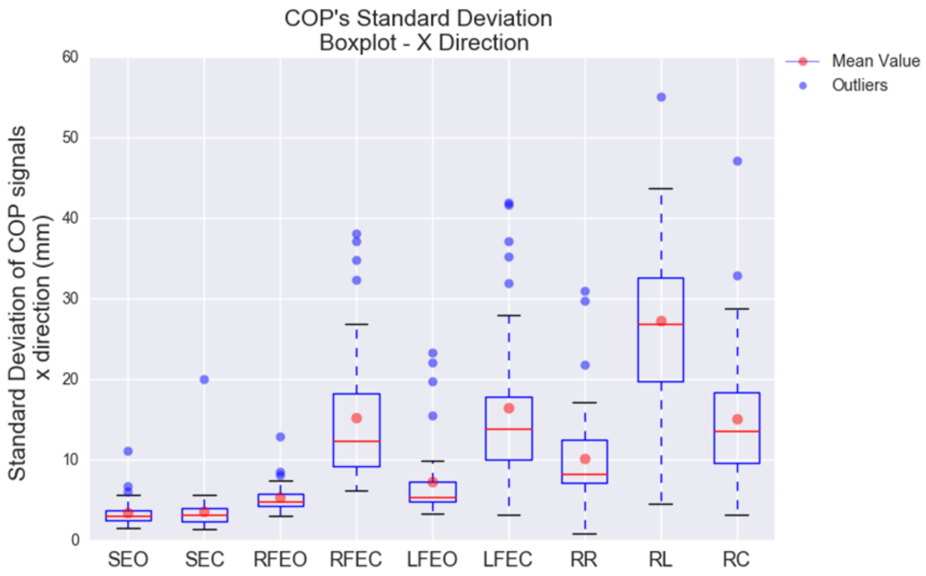

Figure 5.5 - Boxplot representation of COP's standard deviation values for x direction, in each task (N=39).

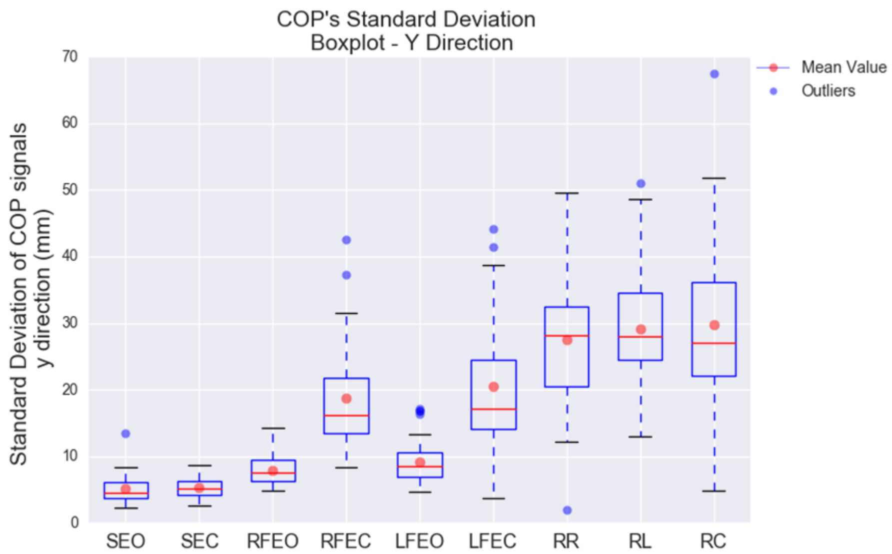

Figure 5.6 - Boxplot representation of COP's standard deviation values for y direction, in each task (N=39)

*** SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

In an overall analysis of the graphics and values, it was observed that in the same tasks, y direction present bigger mean values and a bigger dispersion of values for the parameter in evaluation. It was also noticed that the y direction presents a lower number of outliers when compared with x direction.

It was noticed as well that, although y direction has higher values in comparison with x direction, the standard deviation of COP signals have a similar behavior along all nine tasks, in both directions.

Regarding COP's standard deviation in both directions the following observations were done:

- Regarding x directions, all tasks are statically different from each other ($p<0,05$) with the exception of the following pairs: SEO*/SEC*, RFEC*/LFEC*, RFEC*/RC*, and LFEC*/RC*;
- Regarding y directions, all tasks are statically different from each other ($p<0,05$), but also with a few combinations exceptions: SEO*/SEC*, RFEO*/LFEO*, RFEC*/LFEC*, RR*/RL*, RR*/RC*, RL*/RC*;
- In the x direction, the tasks that present a greater dispersion of data and higher values regarding the mean, median and CI 95%, are RFEC*, LFEC*, and RL. For y direction, the same assertions are true for the RFEC*, LFEC*, RR*, RL*, and RC* tasks.
- The tasks that present the lowest values and the lowest dispersion are SEO* and SEC*;
- Regarding the tasks where the subjects are only standing with one foot, some differences can be seen between those that have visual feedback those that do not have it. The tasks without visual feedback have a greater dispersion of values and higher values when compared with those that have visual feedback.

Table 5-7 contains the values of the tasks that were considered more relevant for the study of this parameter.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Table 5-7 - Mean values, standard deviation (σ), median values, and confidence interval at 95% (CI 95%) values for SEO*, SEC*, RFEO*, RFEC*, LFEO*, and LFEC*, for COP's standard deviation in x and y direction.

	X Direction			Y Direction		
Task	Mean Value ± σ(mm)	Median Value (mm)	CI 95% (mm)	Mean Value ± σ(mm)	Median Value (mm)	CI 95% (mm)
SEO	3,4 ± 1,7	3,1	1,5 – 5,6	5,1 ± 2,0	4,6	2,2 – 8,3
SEC	3,7 ± 2,8	3,2	1,4 – 5,6	5,4 ± 1,6	5,2	2,5 – 8,7
RFEO	5,3 ± 1,7	4,8	3,0 – 7,3	7,9 ± 2,1	7,5	4,8 – 14,4
RFEC	15,1 ± 8,4	12,3	6,1 – 26,8	18,7 ± 7,6	16,2	8,3 – 31,5
LFEO	7,2 ± 4,7	5,4	3,3 – 9,9	9,2 ± 3,3	8,6	4,6 – 13,3
LFEC	16,5 ± 9,6	13,9	3,2 – 27,9	20,5 ± 9,5	17,2	3,8 – 38,5

5.3.2.3 Analysis of Mean velocity of COP signals

For the group of healthy subjects, the mean velocity of COP signals was analyze for each task in each COP direction (x direction and y direction). To analyze this parameter, boxplot graphics were constructed and important values such as mean, median, standard deviation and confidence interval at 95% values were calculated to an easier analysis. Wilcoxon test was use to compare tasks and to verify if there were statistical changes between them (see appendix G).

Regarding this parameter, in a general way, it was not noticed significant changes between tasks ($p>0,05$). Despite this fact, the mean velocity of COP displacement on y direction was considered more relevant for the study due to the fact of presenting a lower number of outliers when compared to the x direction. Figure 5.7 concerns to the boxplots of mean velocity values in y direction.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

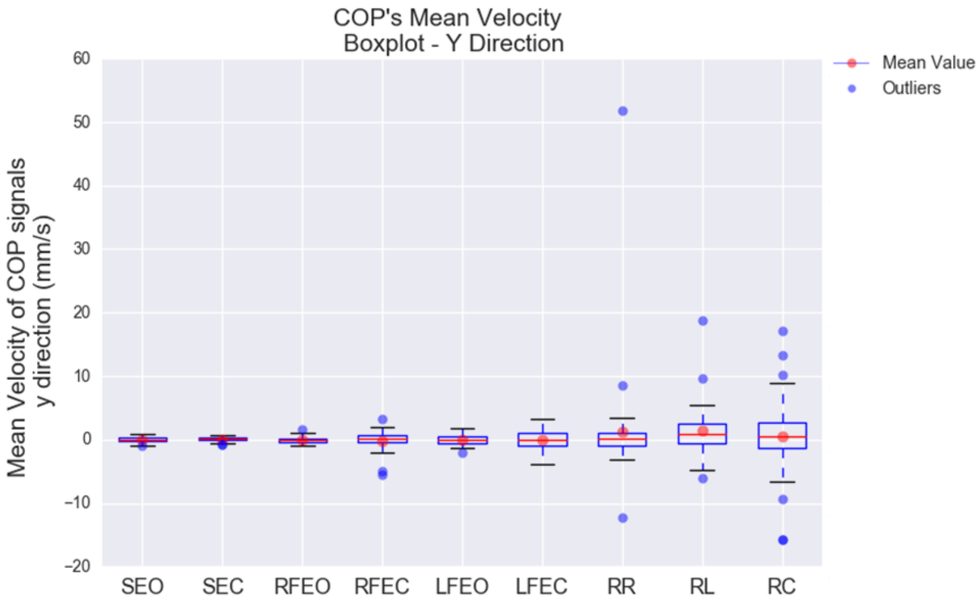

Figure 5.7 - Boxplot representation of mean velocity of COP displacement values for y direction, in each task (N=39).

After the analysis of the boxplots the following conclusions were taken:

- In a general way, the mean and median value for all the tasks is approximate 0 mm/s;
- All boxplots have a low dispersion of values, that means that all values in the same task are very similar;
- The tasks RL* and RC* have a bigger number of outliers when compared to the others.

5.3.2.4 Analysis of total area displacement

Regarding total area displacement of COP arrays, boxplots graphics were used to see the differences between tasks in a group of healthy subjects. For the analysis of this parameter, Wilcoxon test was also used. This test was used to identify statistical changes between tasks (see appendix G).

*** SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Analyzing boxplot graphics, it can be seen some observable differences between tasks (see Figure 5.8).

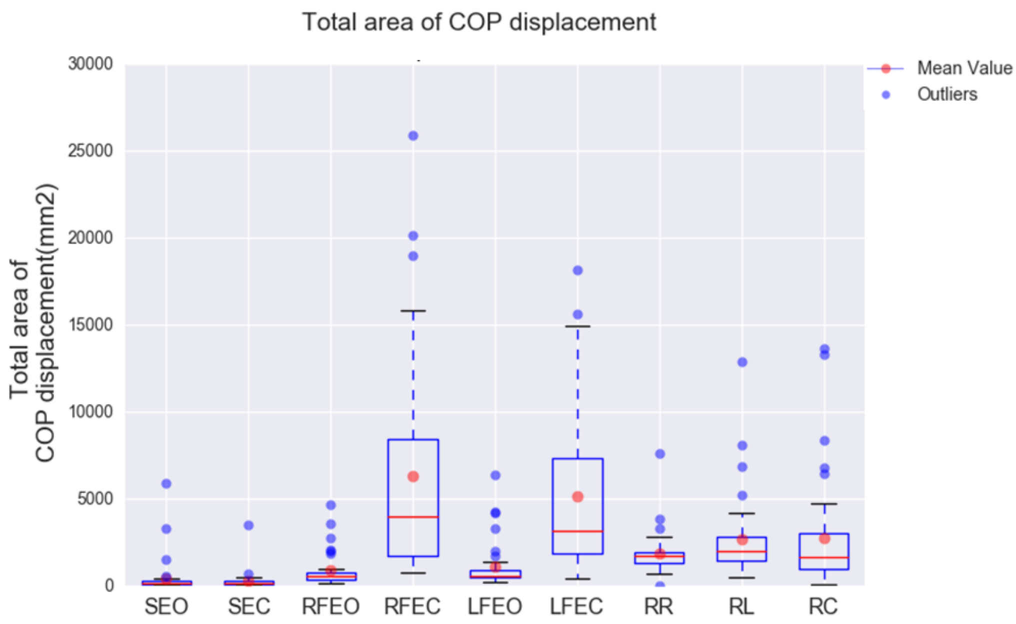

Figure 5.8 - Boxplot representation for total area displacement of COP signals, in each task (N=39).

Regarding this COP parameter, some important observations were done:

- There are a significant difference between almost all of the tasks (p<0,05). However, there are some combinations exceptions: SEO*/SEC*, RFEO*/LFEO*, RFEC*/LFEC*, RR*/RC*, and RL*/RC*;
- It was observed that the tasks that present a larger distribution of values are RFEC* and LFEC*. These are also the tasks that present a bigger mean, median and CI 95% values;
- On the other hand, the tasks that present the lowest distribution of area values are SEO* and SEC*. These are also the tasks with the lowest values, regarding mean value, median value, and CI 95% of the distribution.

Important values regarding the tasks that were considered more important are presented in table 5-8.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Table 5-8 - Mean values, standard deviation (σ), median values, and confidence interval at 95% (CI 95%) values for the most relevant tasks, for COP's total area displacement.

Area			
Task	**Mean Value ± σ(mm^2)**	**Median Value (mm^2)**	**CI 95% (mm^2)**
SEO	436,2 ± 1038,4	159,1	56,2 – 444,1
SEC	289,6 ± 545,6	132,6	62,8 – 474,0
RFEO	896,1 ± 935,7	532,7	163,8 – 955,8
RFEC	6255,3 ± 6100,3	4001,2	807,7 – 15835,6
LFEO	1078,8 ± 1279,2	565,1	251,1 – 1399,8
LFEC	5111,9 ± 4591,6	3142,4	411,8 – 14915,0

5.3.2.5 Analysis of frequencies in COP signals

Frequency analysis was done in both directions (x and y directions). Wilcoxon test was used to compare tasks in the same range of frequencies for each direction. Boxplots analysis was also done for both directions and for each range of frequencies, for all the tasks (see appendix H).

Throughout the Wilcoxon test, some interesting observations were done. For all frequencies in both directions, it was observed that, in a general way, there are no significant differences ($p > 0,05$) between the following tasks: SEO*/SEC*, RFEO*/LFEO*, and RFEC*/LFEC*.

By the analysis of boxplot representations, it was concluded that the range of frequencies that are more interesting are the mean frequency and the frequency at 80% of the power spectrum. These ranges of frequencies were chosen for different reasons: mean frequency is the range of frequency here the boxplots of the tasks are more similar between each other; on the other hand, the frequency at 80% of the power spectrum is the range of frequency where the boxplots of the tasks are more different between each other.

*** SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Figure 5.9 and 5.10 are the representation of mean frequency boxplot in both directions.

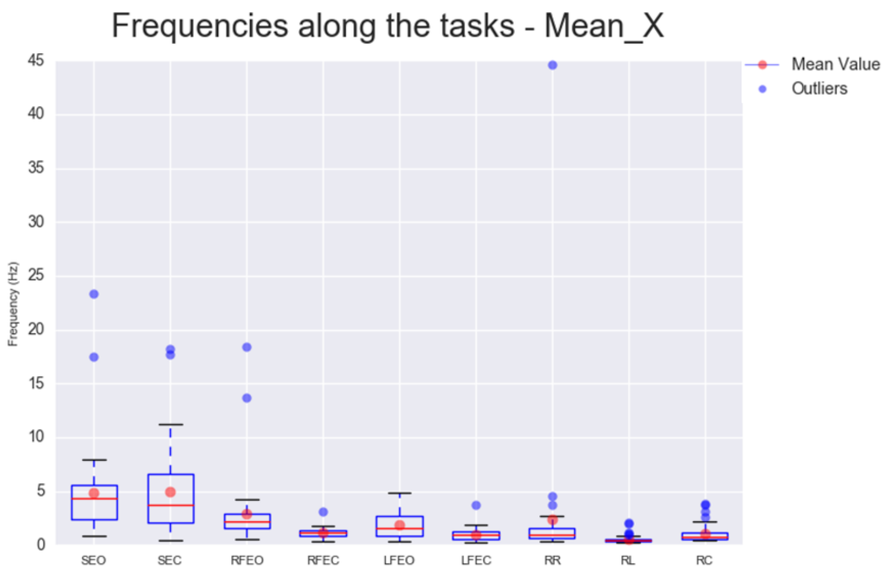

Figure 5.9 - Boxplot representation of the mean frequency in each task for x direction (N=39).

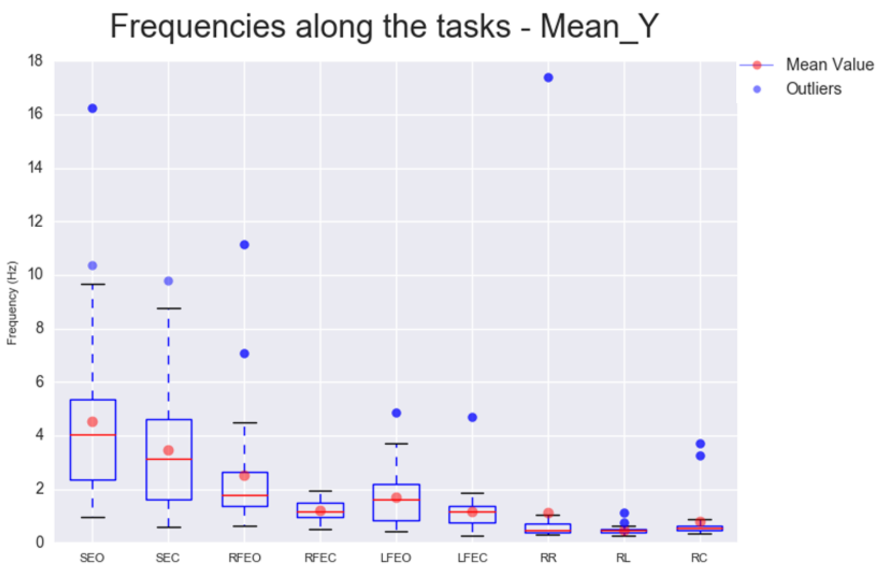

Figure 5.10 - Boxplot representation of the mean frequency in each task for x direction (N=39).

*** SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Regarding mean frequency, some observations were done:

- Like it was mentioned before there was not found significant differences (p > 0,05) between the follow pairs of tasks: SEO*/SEC*, RFEO*/LFEO*, and RFEC*/LFEC*. This statement is true for x direction;
- In x direction SEO* and SEC* are significant different in relation to all other. This statement is not true between SEO*/SEC* (p > 0,05);
- In the y direction, all task are significant different between each other, with the exception of the follow combinations: RR*/RL* and RR*/RC* (p > 0,05);
- Regarding boxplot representation of frequency in both directions, SEO* and SEC* are the tasks that present a bigger dispersion of data (larger boxplots), bigger mean, median and CI 95% values.

Figure 5.11 and 5.12 refer to the representation of boxplot of frequency at 80% of the power spectrum in both directions.

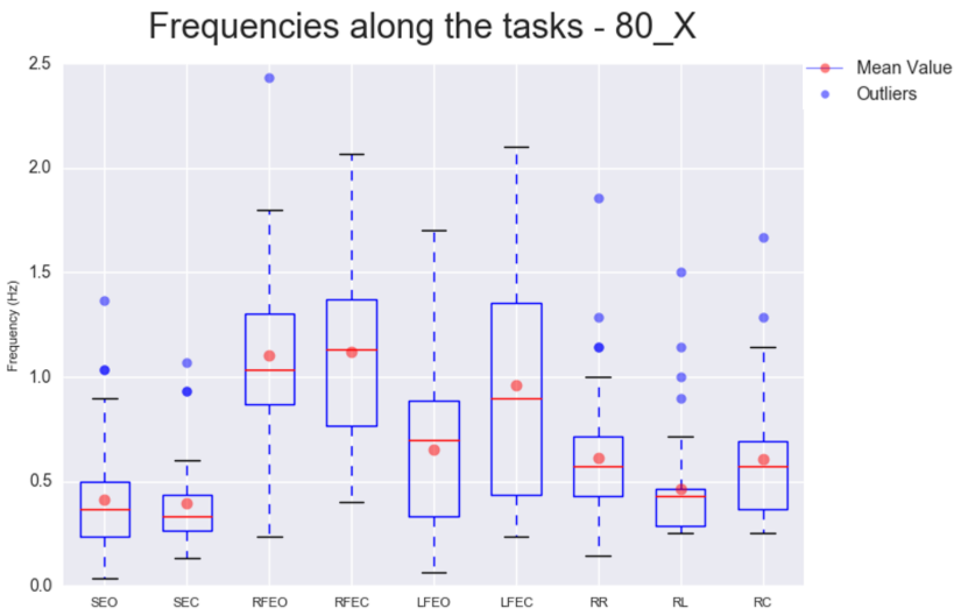

Figure 5.11 - Boxplot representation of frequency at 80% of power spectrum in each task for x direction (N=39).

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

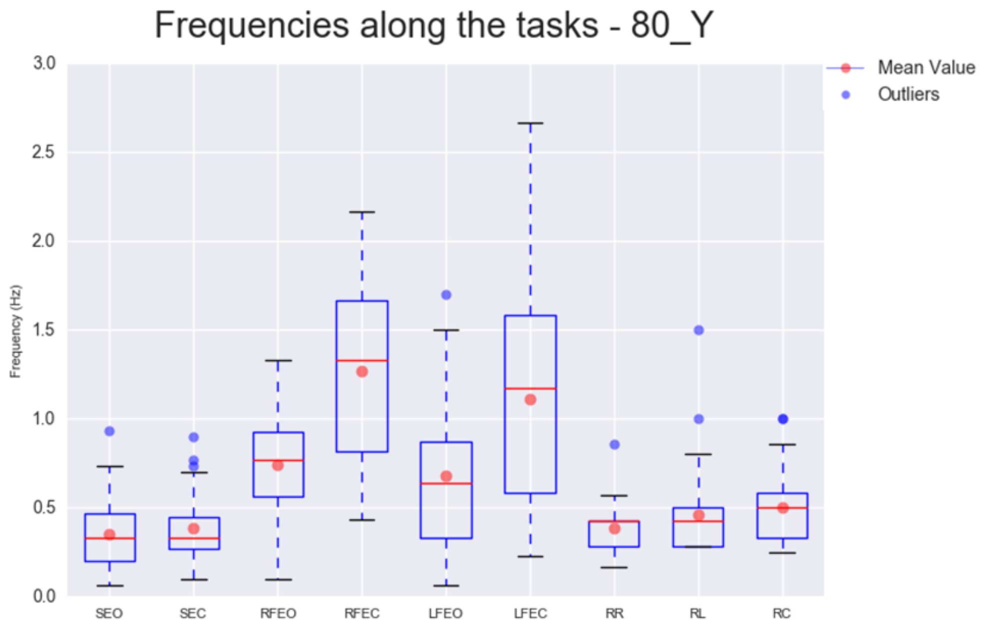

Figure 5.12 - Boxplot representation of frequency at 80% of power spectrum in each task for y direction (N=39).

Regarding frequency at 80% of the power spectrum, some observations were done:

- In both directions, those tasks that do not have significant differences are: SEO*/SEC*, RFEO*/LFEO*, and RFEC*/LFEC* (p > 0,05);
- In x direction, beyond those tasks that were mentioned before, the follow pairs of tasks do not have significant differences between each other: RFEO*/RFEC* and LFEC*/RFEO*;
- In boxplot representations, it can be noticed, for both directions, that the tasks that present the lowest mean and median values are SEO* and SEC*;
- In y directions, in the tasks of standing with just one foot, some differences can be noticed between those tasks that have visual feedback and those that do not have. The tasks that do not have visual feedback (RFEC* and LFEC*), present a bigger dispersion of data (bigger boxplot), bigger mean, median, and CI 95% values;

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

• For x direction, the previous affirmation is not true for both feet. The difference between LFEO* and LFEC* is more predominant, when compared the RFEO with RFEC. For the left foot, when the visual feedback is not present, a bigger dispersion of data can be observed (bigger boxplot), and a bigger mean, median, and CI 95% values.

5.4 Interferential Statistic

Spearman correlation test was used to see if BMI and age have some influence in the parameters in the study, in a group of healthy subjects. It was considered that a Spearman correlation coefficient (ρ) bigger than 0,70 or lower than -0,70 was relevant, and the biomechanical parameters have a strong influence in the EMG or COP parameter in the study (see appendix I).

5.4.1 BMI

BMI values for the group of healthy subjects were correlated between each parameter.

Regarding muscle activation, the BMI values of the subjects were correlated with EMG activation values, for each muscle in each task. There was not found any significant correlation between this EMG parameter and BMI. However, it was noticed that the Spearman correlation coefficient was almost always positive. That means that the values in the evaluation are directly related to each other. When one value increases the other one in the other set of values in evaluation also increase.

EMG frequencies for each muscle, in each range of frequency, along the nine tasks were also correlated to BMI values. For this EMG parameter it was also not found strong correlation between the values of frequencies and BMI.

In concerning to COP parameters, the analysis of the correlation between each parameter, in each direction, along the nine tasks, with BMI values, does not show significant correlations between them. Regarding COP frequencies, the same conclusions were taken, when analyzed the correlation values.

All values for Spearman correlation (ρ) and p-values can be found in appendix I.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

5.4.2 Age

A similar analysis to BMI was done for age. The purpose was to verify if the age factor had a strong influence in EMG and COP parameters.

Regarding muscle activation, it was not found a strong correlation between the muscle activation and age. However, some interesting founding was noticed.

In almost every task, muscles in the abdominal wall, present a negative correlation between the muscle and age values. That means that these two parameters are indirectly related between them. When one value in one of the parameters increases, the other one in the other parameter decrease.

EMG frequencies correlation analysis was not conclusive. Correlation analysis between this two set of values showed that there were not strong correlations between them.

COP parameters analysis also showed not conclusive. COP parameters in both directions, as well the frequencies of COP displacement correlation not showed a strong correlation between the parameter in evaluation and the age of the subjects.

All values for Spearman correlation (ρ) and p-values can be found in appendix I.

5.5 Application of the protocol in clinical context – Ankylosing Spondylitis (AS)

A group of 10 subjects with ankylosing spondylitis also participated in the study. The sample of subjects has characterized according to the acquisition questionnaire (see Table 5-9).

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Table 5-9 - Table representing the characterization of healthy subjects group.

Sex	Age	Weight (kg)	Height (m)	Total Number of subjects	Condition
Female	43 years	53,4 kg	1,53 m	1	AS
Male	**Mean:** 44,6 years **Range:** 25 – 67 years **Standard Deviation:** 14,5 years	**Mean:** 78,2 kg **Range:** 68,7 – 83 kg **Standard Deviation:** 5,4 kg	**Mean:** 1,75 m **Range:** 1,69 – 1,87 m **Standard Deviation:** 0,06 m	9	AS (3 of them with the disease for more than 10 years)

The group of subjects diagnosed with ankylosing spondylitis, present a mean age superior to the group of healthy subjects. This group is represented, almost exclusively by male subjects, unlike the group of healthy subjects.

Using the Mann-Whitney test, it was possible to compare the healthy population described earlier, with a population that suffers from ankylosing spondylitis. Each parameter was evaluated and the comparison between populations was done.

Regarding the mean value of muscle activation, it was noticed that between the muscles in the abdominal wall there was not found significant differences between the two populations ($p > 0,05$). However, in almost wall tasks significant differences were found between the muscles in the lower back of the two populations ($p < 0,05$).

*** SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

In general, in the muscles inserted on the lower back, mean values and median values of the muscle activation in pathologic subjects are bigger when compared, with the same values in the healthy population (see appendix J).

For example, it was noticed that regarding left Iliocostalis (IL) muscle, in the SEC task, the average of the mean values of muscular activation in the group of people with pathology (AS) increases about 4,84% when compared to the healthy population. The median value of this dataset also increases about 4,00% when compared with the group of healthy subjects (Figure 5.13).

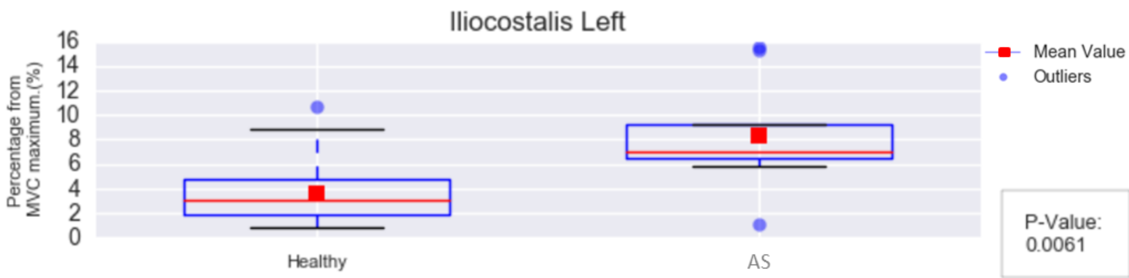

Figure 5.13 - Boxplot representations of the mean value muscle activation for the task SEC*, for the two population in the study (Healthy – healthy subjects and AS – Ankylosing Spondylitis.

A scatter plot was also constructed to compare the two groups, where on the abscissa axis the mean values of the muscle activation during rest for each subject in the group are represented, and on the ordinates axis the mean values of the muscle activation during the task for each subject in the group is represented (see appendix J).

Analyzing this graphical representation, it was noticed that left and right Iliocostalis present a bigger dispersion of values in the group that present pathology when compared with the healthy group (see Figure 5.14). Concerning the other's muscles it was not seen big differences between the two groups.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

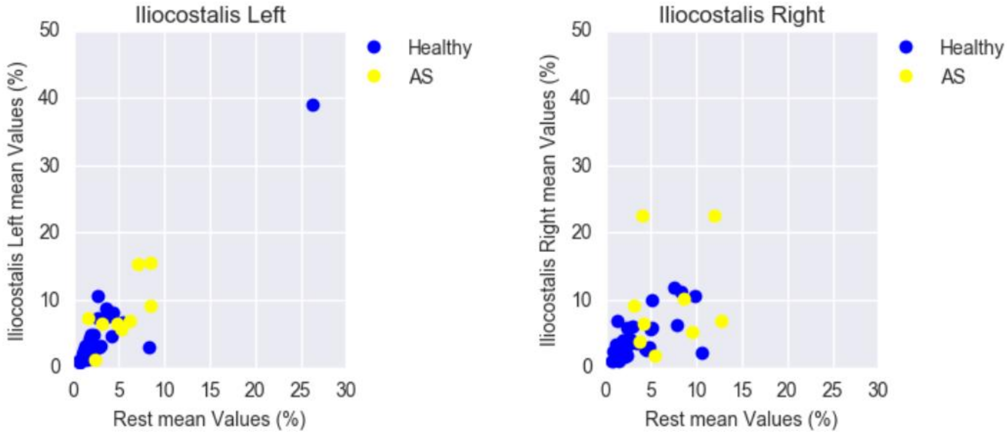

Figure 5.14 - Scatter plot for SEC*, for left and right Iliocostalis. In blue is represented the healthy subjects and in yellow is represented the the subjects diagnosed with ankylosing spondylitis.

Analyzing the task SEC*, for the right Iliocostalis, it can be seen that the group of subjects that present pathology, present a bigger dispersion of values between them. On the other hand, the group of healthy subjects presents a set of values more similar between them.

Regarding the frequencies of EMG arrays, in general, it was not found significant differences between the two populations along the all nine tasks. However, during rest, there was found some differences between the two groups (see appendix J).

During rest, the muscles where were found more significant differences between the two groups, are left Iliocostalis and right Iliocostalis. In general, the frequencies in these muscles in the group of pathologic subjects, present a bigger mean and median values when compared with the group of healthy subjects.

Despite the fact that the muscles that were referred above were the muscles that present the most significant changes between the two groups regarding rest frequencies, the left and right Multifidus also present some significant differences ($p < 0,05$) regarding mean frequency and 80% of power spectrum frequency, respectively. In these, the mean and median values of the group of pathologic subjects also increase when compared with the group of healthy subjects.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Speaking now about COP parameters, some interesting differences were noticed as well.

When analyzed the two groups, in relation to COP's amplitude in both directions, there was not found that many significant differences between them (see appendix J). However, in two tasks, Mann-Whitney test identified some significant differences. Those tasks were RFEO* and LFEO*, in x and y directions respectively.

For instance, in LFEO* the mean value increased 27,8mm when compared to the group of healthy subjects and increased 17,7mm regarding the median value, in relation to the group of healthy subjects.

Standard deviation of COP signals analysis revealed that there were not significant changes between the two groups when concerned to this parameter. The comparison between the two groups and the respective graphics and p-values can be consulted in appendix J.

Regarding the mean velocity, there were not found many significant differences between the two groups, however, in some tasks, it can be seen some interesting comparisons (see appendix J).

Concerning mean velocity of COP arrays in both directions it was noticed that in LFEO*, there were significant differences ($p < 0{,}05$) between the two groups of subjects. Like it was mentioned before, the mean value and the median value of COP's mean velocity in both direction of the group of healthy subjects, round the 0 mm/s. However, in this task, this does not happen for the group of pathologic subjects. Regarding x direction, the mean value decreased 0,78 mm/s and the median value 0,77 mm/s when compared with the same values in the group of healthy subjects. In y direction, the mean value increased 0,92 mm/s and the median value increased 1,24 mm/s in relation to the non-pathologic subjects.

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Still concerning the mean velocity of COP signals, it was noticed that in the task SEO*, although there were not significant differences between the two groups, some discrepancies of values could be seen. In x direction, the mean value for the subjects with pathology increased 0,12 mm/s, and the median value 0,14 mm/s in relation with the subjects without pathology. In relation to y direction, the mean value decreased 0,20 mm/s and the median value 0,29 mm/s. In pathologic subjects, the mean and median value of COP's mean velocity is not 0 mm/s, like in non-pathologic subjects (see Figure 5.15 and 5.16).

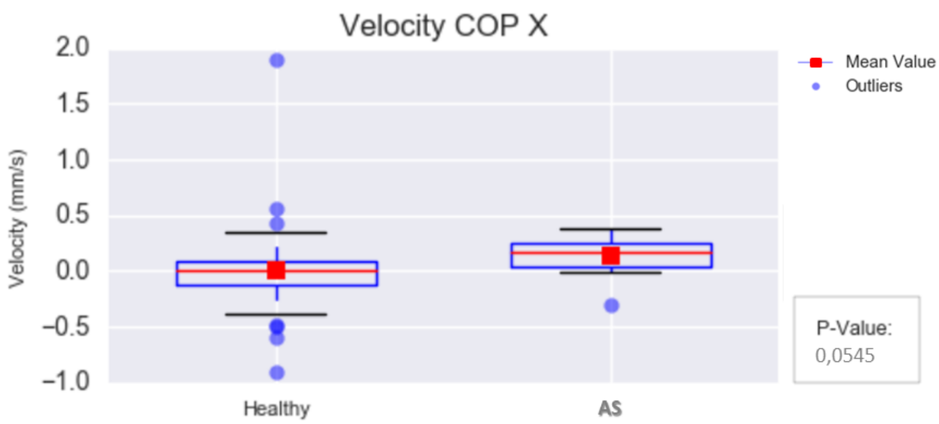

Figure 5.15 - Mean velocity in x direction for SEO*. Representation of both groups of subjects (Healthy, referring to the group of healthy subjects and AS, referring to the group with pathology).

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

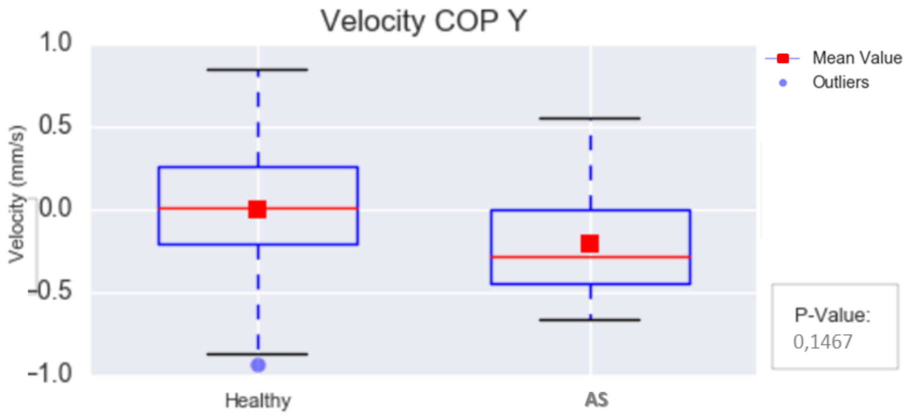

Figure 5.16 - Mean velocity in y direction for SEO*. Representation of both groups of subjects (Healthy, referring to the group of healthy subjects and AS, referring to the group with pathology).

When analyzing the differences between the two groups, regarding total area displacement, it was noticed that only in one task, the groups were significantly different between them ($p < 0,05$) (see appendix J). That task was LFEO*.

In this task, the mean value of pathologic subjects increased about 720,73mm^2 and the median value increased about 823,69mm^2, in relation to the group of subjects without pathology.

On the topic of COP frequencies, it was noticed that the two groups of subjects do not have many significant differences between them (see appendix J). However, the tasks SEO* and SEC* present a significant difference between the two groups, regarding mean frequency in both directions.

In the case of SEO*, the mean frequency values of the group of subjects that have pathology decrease when compared with the group of healthy subject. Also, the CI at 95% also decreases significantly (see Figure 4.17).

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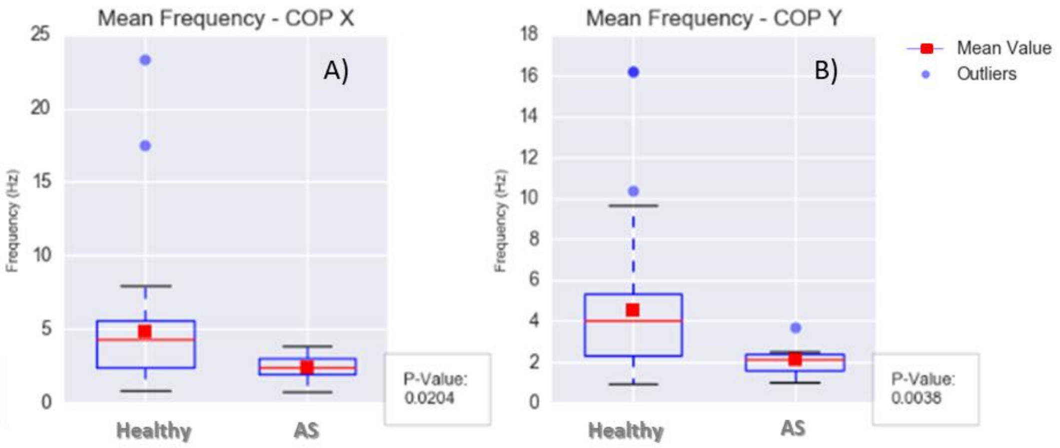

Figure 5.17 - Mean frequency of COP signals in both directions for the task SEO*. A) Representation of boxplots for both groups in x direction; B) representation of both groups in y direction.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

6

6. Results Discussion

In this chapter, the most important results that were obtain will be discuss.

The main goal of this study is to define the posture of a group of healthy subjects using EMG and posturography, nevertheless, a group of ankylosing spondylitis subjects was also studied, in order to validate this goal.

Although there is a lot of posturography studies done in order to compare a healthy population with a pathologic one, these studies are not yet standardized and their conclusions are not yet concordant with each other's. Also, it is known that the musculoskeletal tissues have a very important role in maintaining a correct posture and permitting the correct movement of the human body during an outside destabilization. However, there was not found studies that use EMG as an auxiliary study to posturography in order to analyze posture and equilibrium.

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Due to the reasons presented above, the comparison of this study with others done in the area has very difficult. Most of the studies only performed or posturography or only EMG, so it was very difficult to associate both studies in one. As far as it is known, this is the first study that assesses extensively the posture, both at posturography level as well as EMG level.

The present study revealed interesting results, regarding the definition of posture in a group of healthy subjects, as well as regarding the comparison between healthy subjects and subjects with ankylosing spondylitis. And, although not many studies have been found that were similar to the present one, it was found some results that were concordant with the results of this study.

Regarding the definition of posture in a group of healthy subjects, some results were found in the bibliography that corroborates the results obtained.

Concerning to muscle activation, a study performed by O'Sullivan et al [28], demonstrated that during standing posture the anterior abdominal musculature has a very important role in the maintenance of this posture. This study referred also that the muscle that has the bigger contribution to maintaining the standing posture is the Rectus Abdominis.

On the results of this study, it can be noticed that during all the tasks, in a general way, the Rectus Abdominis muscle have always a similar value for muscle activation. That means that, during the performance of all tasks, Rectus Abdominis is always active in the same way, in order to maintain the upright position and the correct position of the torso.

Still concerning to muscle activation, it was noticed that during the tasks SEO* and SEC* each muscle present a similar activation in both ways regarding the sagittal plane. It is important to refer, that this tasks, are the tasks that required that subjects stay with both feet on the ground during 30 seconds without moving.

In these tasks, in the same muscle, the left and the right side are strongly correlated between them, which propose that during these tasks the left and right side work together to maintain a correct and stable posture.

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Regarding EMG frequencies, it was evaluated four ranges of frequencies: peak frequency, mean frequency, median frequency and, the frequency at 80 % of the power spectrum.

Rectus Abdominis do not present significant differences between tasks, in all ranges of frequencies. That corroborates the statement done before, that Rectus Abdominis have an important role in the maintenance of standing positions. On the other hand, the other muscles present different values between each task that was performed.

Regarding lower back muscles, it was noticed that existed differences in those tasks where the subjects were standing only with one foot, between those that have visual feedback (RFEO* and LFEO*) and those that do not have it (RFEC* and LFEC*). The fact of not having visual feedback brings impairments in postural control and causes more destabilization. Those tasks that do not have visual feedback, present a lower mean frequency when compared to those tasks that have visual feedback.

Still regarding muscular frequency, it was noticed that each muscle have a significant difference in each task when compared to the rest position. During rest, the subjects were lay down on a marquise and not performing any type of effort in torso muscles. That said, it was confirmed that when performed any task in the protocol, the muscle activated and respond according to the needs that the subjects have to maintain a correct posture and to not suffering falls.

Regarding COP analysis, some results also corroborate with some conclusions found on the bibliography.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Rougier [65] concluded in his study that the fact of not having visual feedback on the performance of some kind of task during a postural control assessment provokes a bigger variety of COP displacements. That was also verified in the current study. The tasks that present a bigger variety of values, in almost every COP parameter analyzed, were those tasks that the subjects were supported only by one foot and their eyes were closed (RFEC* and LFEC*). Although the task of standing with both feet on the ground with eyes close (SEC*) is also a task without visual feedback, this variety of values is not so explicit in this task. The tasks RFEC* and LFEC* are tasks that provoke a bigger destabilization, when compared to SEC*, because of not having only one impairment. These tasks have a double impairment: the fact of not having visual feedback and the fact of the support is only done by one foot.

The fact of SEC* not having as much variety of values when compared to the other tasks that do not have visual feedback (RFEC* and LFEC*) is also confirmed by the bibliography. Bugnariu [54], performed a study and concluded that, when the surface is static and do not have any destabilization on it, the somatosensory have a bigger role in maintaining the upright position, when compared to the visual system. And that is the case in this study. The subjects are placed on a stable support surface with both feet on the ground.

In a general way, in almost all parameters, it was noticed that the tasks SEO* and SEC* do not have significant differences between them. This only proved the statement that was done before, that when having a stable surface and not having any more destabilizations occurring, the visual feedback does not have a big importance in postural control.

The following pairs of tasks do not have also, a significant difference between them: RFEO* with LFEO*, and RFEC* with LFEC*. In this case, can be concluded that performing the same task with the right or left foot do not have almost any difference regarding the data recorded.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Regarding COP parameters, the parameter that stands out more, when compared to all others is the mean velocity of COP displacement. It was noticed that this parameter have similar values between all tasks. In all tasks, this parameter is very close to zero in both directions.

Mean velocity is the mean value of COP velocity array. That means that during the performance of any task, the mean velocity is close to 0mm/s. During a postural control assessment, the human body pretends to stay in the same position and maintain a correct posture in order to not fall. And that is what is occurring when the mean velocity is close to zero. That means that, although the human body is suffering some destabilizations, it can maintain a correct posture and stay almost in the same position. The fact of mean velocity is close to zero proved that this group of healthy subjects can control their posture in a correct way.

When concerning COP frequency, and according to the bibliography, the range of frequency that better represent COP changes regarding postural control is the frequency at 80% of power spectrum [12]. This information is in agreement with the results obtained in this study.

The frequency at 80% of the power spectrum is that one that presents more differences between tasks, especially in the y direction. In these, the biggest differences can be noticed in those tasks that are only supported by one foot, between those that have visual feedback and those that do not have it. Those that do not have visual feedback present a bigger dispersion of data compared to those that have it.

When analyzing the EMG parameters at the same time as the COP parameters, it can be conclude that a bigger COP displacement also brings a bigger muscle activation. It can be concluded that in order to compensate the disequilibrium the muscles activate and provoke a response to the outside stimulus.

All the parameters described above were correlated with BMI and age. This analysis was not conclusive, due to the fact that strong correlation coefficients (ρ) were not found.

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This weak correlation between the parameters and BMI and age could be due to the fact that the sample in the study was not very heterogeneous. The subjects had a very close age between each other, and their height and weight were also not very dispersed.

Based on the bibliography, age and BMI have a strong influence in EMG and COP parameters.

Regarding muscle activity, it was expected that this had a negative correlation with BMI or age. A bigger BMI can be associated with a bigger percentage of body fat, what can influence the EMG signal negatively. Age also contributes negatively to muscle activation values. Age brings impairments in movement and to muscle activation, so it was expected a negative contribution of this parameter. The same thing was expected, regarding EMG frequency. It was expected that BMI and age had a negative contribution to frequency values.

COP parameters, on the other hand, were expected that BMI and age had a positive contribution on these parameters. With aging, comes muscle weakness and difficulties in maintaining the right posture. These provoke a greater range of values in COP parameters. BMI also can bring impairments in posture. As it was said before, the BMI is associated with a bigger weight, and that said bigger difficulties in maintaining the equilibrium.

The group of subjects diagnosed with ankylosing spondylitis was used in order to validate the analysis done before in a group of healthy subjects. Some relevant differences could be found between both groups.

About muscle activation, there was not found significant differences between Rectus Abdominis muscles. Like it was mentioned before, these muscles have a big role in the maintenance of upright standing position and it was concluded that this muscle works in the same way in the group of pathologic subjects. However, in the muscles inserted on the lower back, some significant differences were found, especially in Iliocostalis muscles.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

In Iliocostalis muscles, it was noticed that the subjects presenting ankylosing spondylitis have bigger values of activation when compared to the group of healthy subjects. The same thing occurs in some task in Multifidus muscle, however, the difference is not so clear. Also regarding Iliocostalis, it was seen some significant differences between the two groups, concerning muscle frequency during rest. During rest, this muscle presents bigger values when compared to the same muscle in the group of healthy subjects.By the previous affirmation, it can be concluded Iliocostalis muscles in patients with ankylosing spondylitis, are more active during the tasks and also during rest position.

The fact of not having a clear difference in Multifidus muscle could be explained by the fact that this muscle is not a superficial muscle and is very hard to capture his electromyographic signal with superficial electrodes [56].

Regarding COP parameters, it was not found that many significant differences between the two groups. In some tasks and some parameter, there was found some differences, however, there were not sufficient to say that the two groups are statistically different.

Although there were not found statistical differences between the two groups in almost all parameters, mean velocity present some interesting results in the tasks of standing with both feet (SEO* and SEC*).

In these tasks, it can be noticed that the value of mean velocity is not zero like in the subjects with any pathology. This may suggest that these subjects have difficulties in maintaining the upright standing positions and have more body sway when compared to the healthy population.

***SEO = Standing with eyes open; SEC = Standing with eyes close; RFEO = One leg stand, right leg and eyes open; RFEC = One leg stand, right leg and eyes close; LFEO = One leg stand, left leg and eyes open; LFEC = One leg stand, left leg and eyes close; RR = Reaching an object on the right side of the subject with his left hand; RL = Reaching an object on the left side of the subject with his right hand; RC = Reaching an object in front of the subject dominant hand.**

Concerning COP frequencies, although it was said before that the range of frequencies that better represent postural changes is the frequency at 80% of the power spectrum, there was not found significant changes between the two groups of subjects regarding this frequency range. Due to this fact it can be concluded that regarding COP frequencies the two groups are very similar to each other and there are not an important parameter in order to compare the two groups.

By analyzing the results, it was possible to conclude that the analysis of EMG data was very important. Without this analysis, it would not be possible to distinguish the group of healthy subjects with the group that presented ankylosing spondylitis.

7

7. Conclusions and future perspectives

The main goal of this project was to define the normal standing posture of a group of healthy subjects. In order to understand the posture was necessary to evaluate electrophysiological parameters as well as biomechanical parameters. It was also possible to evaluate a group of subjects diagnosed with ankylosing spondylitis, in order to compare with the healthy posture.

For achieve the main goal of the project, an acquisition protocol was constructed. This protocol was approve by the Centro Hospitalar Lisboa Ocidental committee.

The pursuit of the main aim it was only possible due to the construction of a set of steps that were completed:

- Definition of the biomechanical and electrophysiological parameters to be analyzed;
- Development of a protocol for the acquisition of biomechanical and physiological parameters;
- Acquisition of data in a sample of people without pathology;
- Analysis of biomechanical and electrophysiological parameters and correlation of demographic data;
- Development of a clinically relevant normative database for a sample of subjects without pathology;
- Elaboration of the posture profile of the person without pathology, in the standing positions;

Having into account that there was not found much information about this subject, this project emerges as a necessity. It is also known there are many factors that can cause impairments in the postural control system, it is important to define what is normal in order to compare to an abnormal case.

Having this into account, the main goal of the protocol is to assess postural control changes and to evaluate how a healthy subject behaves in some abnormal situations. Based on the data collected through the protocol, some important parameters were evaluated.

There are unlimited applications, after the normal standing position is defined, and one of them is application in a clinical assessment in order to evaluate pathologies that bring impairments in postural control.

The construction of a simple protocol and the use of low cost instruments can facility the use of this type of tests in clinical assessment of posture disturbances. Also, the fact of this test has a low duration can also facility the use of this type of test in a clinical context. This all protocol has a duration of about 30 minutes.

The bibliographic review in this topic turned out scarce. There are a lot of studies using posturography in order to compare two different groups or to evaluate a group with pathology with a group without pathology, however, there were not found any study that defines the normal standing position in a group of healthy subjects.

Regarding EMG studies, some studies were found that evaluate the standing position, however there do not go much further into the subject, or the studies were not done in trunk muscles. Most of the studies are done in inferior members instated of the trunk muscles, even though is known that the trunk muscles have an important role in maintaining the upright standing position.

It was also not found studies that correlate EMG data with posturographic data, so the comparison between this study with others was difficult.

In the developing of this project it was noticed that the EMG analysis bring a great help in order to evaluate postural control changes. Muscle activity can give us the information about the muscles that have a bigger contribute to postural control and those that do not have.

Regarding muscle activity, it was concluded that Rectus Abdominis have an important role in maintaining the torso in a correct position in order to maintain equilibrium and stability. The relation between the other muscles and postural control are not explicit.

This statement is proved by the analysis of a group of subjects with pathology. The major differences between the two groups are between muscle activities. Without EMG analysis there was not found major statistical differences between the two groups.

During the development of this study, some impairment were found. One of those impairments is related to the sample of subjects in evaluation. The sample in evaluation has a mean age rounding 25 years old, and a standard deviation of 9,1 years old, so it was only possible to evaluate a very young group of subjects and define the normal posture for that range of age. Due to that impairment, the influence of aging in postural control was not conclusive.

During the performance of the protocol, it was also possible to understand that the subjects diagnosed with ankylosing spondylitis had some difficulties in some parts of the protocol, especially on the performance of those tasks where the subjects had to stand only with one foot during 30 seconds. Most of the patients could not perform the task until the end because of pain, or just because they were not able to perform it.

Another impairment that was found, was regarding the MVC performance. Like it was mentioned before, performing MVC tests in untrained subjects or pathologic subjects can cause some abnormal values. This was verified in some values, especially in external Obliques muscles.

At last but not least, the EMG equipment. This study was conducted during summer, and because of that the correct placement of the electrodes along all the protocol has difficult. The electrodes sometimes disconnected from the human body contaminate the data that was recorded.

Besides all the impairments encountered during the study, it was concluded that this project has some interesting results and the main goal was achieved. This theme has unlimited applications and can be even more developed. This type of test can be used in so many different pathologies that can bring impairments on the postural control system.

For the future studies in this area some recommendations can be done.

- As it has said before this protocol has a low duration, however this duration can be even lower. Tasks of reaching can be remove from the protocol, due to the fact that were not consider relevant.
- One of the impairments of this study was the low range of ages in the sample. So for the future projects, the application of the protocol in a bigger range of ages must be done.

- Another improvement to the study has to do with the fact of the disconnection of the electrodes during the acquisition of data. To counter this gap, a kind of band that surrounds the acquisition location can be constructed in order to maintain the electrodes in place during the acquisition of data.
- During the analysis of the data, some ideas come up. It was also interesting to see the time of response of muscle activity and compare to time that was taken until the correspondent movement in COP displacement. It is interesting to see if a pathologic set of subjects have a bigger response time when compared to a healthy population.

Regarding the present study, it can be concluded that the main goal of the study was achieved and the study revealed interesting results for the scientific community in general, and more specific for the postural control assessments.

This study helped to define a normal posture in a group of healthy individual, but this is not the end of the road. There still are so many different analyses that can be done and so many different parameters that can be evaluated in order to better understand postural control changes. This system has some many other systems evolved, that the analysis of all of them is very important to fully understand the postural control system.

The present study comes as an incentive for further studies in this area, in order to obtain a better understanding of the postural control system.

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A

Appendix A

Questionário de Caracterização da Amostra

O presente questionário tem como principal objectivo recolher informações para caracterizar a amostra de um estudo científico. Este estudo visa a definir o padrão normal da postura erecta. Os dados recolhidos são anónimos e serão usados exclusivamente para a caracterização da amostra no presente estudo.

Código: _______ (não preencher este campo)

1. Idade: __________ anos

2. Sexo: □ Masculino □ Feminino

3. Altura: __________ m

4. Peso: ___________ kg

5. Nacionalidade:

□ Portuguesa

□ Outra Qual?_______________________________

6. Habilitações literárias: _________________________

7. Profissão:_____________________________________

8. Estado Civil: __________________________________

9. Mão dominante:________________________________

B

Appendix B

Consentimento Informado

Folha de Informação

Caro (a) Senhor (a),

O meu nome é Ana Mendes do Departamento de Física e realizo o mestrado integrado em Engenharia Biomédica na Faculdade de Ciências e Tecnologia na Universidade Nova de Lisboa. Gostaria de pedir a sua colaboração para a concretização de um estudo de investigação sob o tema "Desenvolvimento de base normativa em patologias do foro reumatológico baseado em posturografia e electromiografia". Informo que para a realização deste estudo será necessário a recolha de imagens da secção em estudo, o tronco.

Informo que a recolha de dados será feita na FCT-UNL, recorrendo ao equipamento *Biosignalsplux Kit/Plataforma de forças*.

Em qualquer momento do estudo é livre de desistir, se assim o pretender. Ao longo de todo este processo não receberá nada em troca, visto que a sua participação é voluntária. Gostaria de salientar que, com a sua colaboração, estará não só a contribuir para a realização deste projeto de investigação, mas também para um maior conhecimento na área científica, promovendo o desenvolvimento de novas metodologias de prevenção e diagnóstico de alterações da postura, que poderão beneficiar a sociedade no futuro.

Todos os dados recolhidos nas etapas anteriormente descritas serão anónimos e confidenciais e não serão publicadas quaisquer fotografias que permitam a sua identificação.

Se existirem dúvidas sobre o preenchimento correto deste questionário, por favor contacte 212948576.

Confirmo que expliquei à pessoa abaixo indicada, de forma adequada e inteligível, os procedimentos necessários ao ato referido neste documento. Respondi a todas as questões que me foram colocadas e assegurei-me de que houve um período de reflexão suficiente para a tomada da decisão.

(Assinatura legível)

____

Data: …../…../…..

Ao Participante

Por favor, leia com atenção todo o conteúdo deste documento. Não hesite em solicitar mais informações se não estiver completamente esclarecido(a). Verifique se todas as informações estão corretas. Se tudo estiver conforme, então, assine este documento.

Declaro ter compreendido os objectivos que me foram propostos e explicados. Foi-me concedida a oportunidade de esclarecer todas as dúvidas sobre o assunto e para todas elas obtive uma resposta esclarecedora. Tive tempo suficiente para refletir sobre esta proposta, pelo que declaro que autorizo/Não autorizo (riscar o que não interessa) o ato indicado, bem como os procedimentos diretamente relacionados que sejam necessários no meu próprio interesse e justificados por razões fundamentadas.

(Assinatura legível)

____

Data: …../…../…..

Consentimento Informado

Folha de Informação

Caro (a) Senhor (a),

O meu nome é Ana Mendes do Departamento de Física e realizo o mestrado integrado em Engenharia Biomédica na Faculdade de Ciências e Tecnologia na Universidade Nova de Lisboa. Gostaria de pedir a sua colaboração para a concretização de um estudo de investigação sob o tema “Desenvolvimento de base normativa em patologias do foro reumatológico baseado em posturografia e electromiografia”, que se encontra inserido no projecto MyoSpa. Informo que para a realização deste projecto será necessário a recolha de imagens da secção em estudo, o tronco.

Informo que a recolha de dados será feita no *CEDOC* (Centro de Estudos de Doenças Crónicas) da Faculdade de Ciências Médicas da Universidade Nova de Lisboa, recorrendo ao equipamento *Biosignalsplux Kit/Plataforma de forças*.

Em qualquer momento do estudo é livre de desistir, se assim o pretender. Ao longo de todo este processo não receberá nada em troca, visto que a sua participação é voluntária. Gostaria de salientar que, com a sua colaboração, estará não só a contribuir para a realização deste projeto de investigação, mas também para um maior conhecimento na área científica, promovendo o desenvolvimento de novas metodologias de prevenção e diagnóstico de alterações da postura, que poderão beneficiar a sociedade no futuro.

Todos os dados recolhidos nas etapas anteriormente descritas serão anónimos e confidenciais e não serão publicadas quaisquer fotografias que permitam a sua identificação.

Se existirem dúvidas sobre o preenchimento correto deste questionário, por favor contacte 212948576.

Confirmo que expliquei à pessoa abaixo indicada, de forma adequada e inteligível, os procedimentos necessários ao ato referido neste documento. Respondi a todas as questões que me foram colocadas e assegurei-me de que houve um período de reflexão suficiente para a tomada da decisão.

(Assinatura legível)

____

Data: …../…../…..

Ao Participante

Por favor, leia com atenção todo o conteúdo deste documento. Não hesite em solicitar mais informações se não estiver completamente esclarecido(a). Verifique se todas as informações estão corretas. Se tudo estiver conforme, então, assine este documento.

Declaro ter compreendido os objectivos que me foram propostos e explicados. Foi-me concedida a oportunidade de esclarecer todas as dúvidas sobre o assunto e para todas elas obtive uma resposta esclarecedora. Tive tempo suficiente para refletir sobre esta proposta, pelo que declaro que autorizo/Não autorizo (riscar o que não interessa) o ato indicado, bem como os procedimentos diretamente relacionados que sejam necessários no meu próprio interesse e justificados por razões fundamentadas.

(Assinatura legível)

____

Data: …../…../…..

C

Appendix C

Force Platform
Data Sheet

SPECIFICATIONS

> Axis: 1(Z)
> Sensitivity: ±0.05%
> Gain: 491.605
> Consumption: 56 µA (per cell)
> Range: up to 800 kgf (200 kgf per cell)
> Construction: Aluminum

FEATURES

> 4 independent steel load cells
> 360° protractor drawn on the top face
> Increased resistance to deformations
> Adjustable feet for manual leveling
> High-performance feet design
> Equidistant load cells (diagonally placed)
> Separate signal conditioning per load cell for better signal-to-noise ratio

APPLICATIONS

> Center of gravity assessment
> Biomedical research
> Physiotherapy
> Biomechanics
> Rehabilitation research
> Sports Research

GENERAL DESCRIPTION

Center of gravity distribution, jump analysis, weight assessment and force production capacity, are just some of the applications where force assessment is important. Our robust yet lightweight 1D force platform enables uncompromised data acquisition both in lab and field measurements.

Fig. 1. biosignalsplux Force Platform.

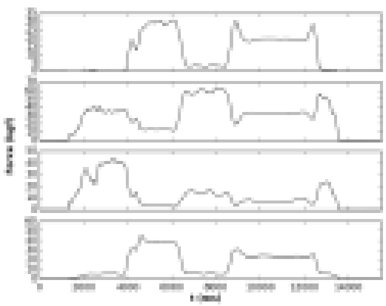


Fig. 2. Typical force platform output with one channel per load cell (acquired with OpenSignals)

Fig. 3. Top face protractor installed on the Force Platform

PLUX – Wireless Biosignals, S.A.
Av. 5 de Outubro, n.º 70 – 8
1050-059 Lisbon, Portugal
plux@plux.info
http://biosignalsplux.com

biosignalsplux Force Platform
Data Sheet

TRANSFER FUNCTION

[0 kgf, 200 kgf] [1]

$$Weight\ (kgf) = \frac{ADC\ .\ C}{V_{FS}\ .\ (2^{nbits} - 1)}$$

$$C = 406.831\ kg.mV/V$$

V_{FS} – Output voltage in mV/V @ 200kgf (factory calibrated value specific to each cell)
ADC – Value sampled from the channel
$nbits$ – Number of bits of the channel[2]

CENTER OF PRESSURE

[[-225, 225] mm, [-225, 225] mm]

$$CoPx\ (mm) = \frac{W}{2} \cdot \frac{C2 + C3 - C1 - C4}{C2 + C3 + C4 + C1}$$

$$CoPy\ (mm) = \frac{L}{2} \times \frac{C2 + C1 - C3 - C4}{C2 + C3 + C4 + C1}$$

If $C2 + C3 + C4 + C1 = 0$
then $CoPx = 0$ and $CoPy = 0$

W = 450 mm (platform width)
L = 450 mm (platform length)
$C1$ – Weight (in kgf) on the channel with the cable marked in blue
$C2$ – Weight (in kgf) on the channel with the cable marked in black
$C3$ – Weight (in kgf) on the channel with the cable marked in yellow
$C4$ – Weight (in kgf) on the channel with the cable marked in red

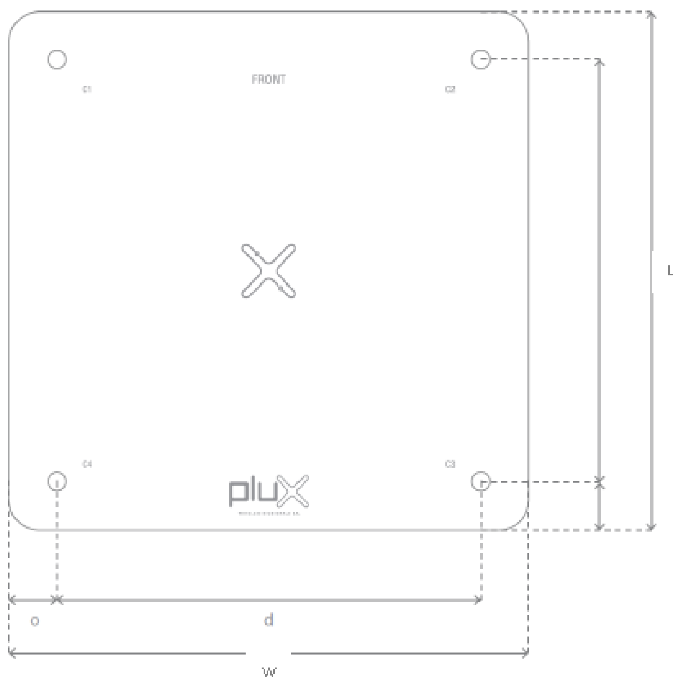
1 Per cell.

2 The number of bits for each channel depends on the resolution of the Analog-to-Digital Converter (ADC); in biosignalsplux the default is 16-bit resolution ($n = 16$), although 12-bit ($n = 12$) and 8-bit ($n = 8$) may also be found.

biosignalsplux Force Platform
Data Sheet

PHYSICAL CHARACTERISTICS

> **W x L:** 45x45 cm
> **Max Height (recommended):** 6.7 cm
> **Min Height:** 5.8 cm
> **Min Height (using the optional feet):** 4 cm
> **Total Weight**: 9 kg



ORDERING GUIDE

Reference	Package Description
SENSADV-FORPLAT1	Sturdy unidimensional platform with four independent load cells for jump, leg press, and similar setups.
BIOKITFSR1	Sturdy unidimensional platform with four independent load cells for jump, leg press, and similar setups, bundled with a wireless 4-channel hub for real-time wireless data acquisition and display or logging into an internal memory card.

Appendix D

Spearman correlation coefficient (ρ) between tasks for each muscle in evaluation.

D 1-6 – Correlation coefficient (ρ) between each task, for each muscle in evaluation. **p-value < 0,05.

					Right Obliques					
		SEO	**SEC**	**RFEO**	**RFEC**	**LFEO**	**LFEO**	**RR**	**RL**	**RC**
(ρ)	**SEO**	1								
	SEC	0,96 **	1							
	RFEO	0,87 **	0,87 **	1						
	RFEC	0,80 **	0,76 **	0,84 **	1					
	LFEO	0,72 **	0,70 **	0,77 **	0,80 **	1				
	LFEC	0,47 **	0,42 **	0,48 **	0,65 **	0,70 **	1			
	RR	0,89 **	0,87 **	0,82 **	0,83 **	0,76 **	0,55 **	1		
	RL	0,78 **	0,76 **	0,69 **	0,70 **	0,69 **	0,53 **	0,77 **	1	
	RC	0,91 **	0,89 **	0,83 **	0,81 **	0,76 **	0,50 **	0,87 **	0,82 **	1

		Left Obliques								
		SEO	SEC	RFEO	RFEC	LFEO	LFEO	RR	RL	RC
(ρ)	SEO	1								
	SEC	0,99 **	1							
	RFEO	0,88 **	0,87 **	1						
	RFEC	0,69 **	0,71 **	0,82 **	1					
	LFEO	0,86 **	0,85 **	0,85 **	0,79 **	1				
	LFEC	0,67 **	0,65 **	0,72 **	0,74 **	0,81 **	1			
	RR	0,83 **	0,82 **	0,75 **	0,69 **	0,87 **	0,74 **	1		
	RL	0,91 **	0,90 **	0,82 **	0,73 **	0,93 **	0,75 **	0,89 **	1	
	RC	0,86 **	0,88 **	0,76 **	0,71 **	0,88 **	0,78 **	0,87 **	0,92 **	1

		Right Iliocostalis								
		SEO	SEC	RFEO	RFEC	LFEO	LFEO	RR	RL	RC
(ρ)	SEO	1								
	SEC	0,97 **	1							
	RFEO	0,79 **	0,78 **	1						
	RFEC	0,61 **	0,64 **	0,85 **	1					
	LFEO	0,79 **	0,73 **	0,76 **	0,55 **	1				
	LFEC	0,68 **	0,66 **	0,50 **	0,41 **	0,69 **	1			
	RR	0,70 **	0,69 **	0,70 **	0,57 **	0,69 **	0,54 **	1		
	RL	0,73 **	0,70 **	0,72 **	0,60 **	0,64 **	0,45 **	0,82 **	1	
	RC	0,67 **	0,68 **	0,65 **	0,57 **	0,57 **	0,45 **	0,77 **	0,85 **	1

		Left Iliocostalis								
		SEO	**SEC**	**RFEO**	**RFEC**	**LFEO**	**LFEO**	**RR**	**RL**	**RC**
	SEO	1								
	SEC	0,98 **	1							
	RFEO	0,86 **	0,84 **	1						
	RFEC	0,63 **	0,63 **	0,68 **	1					
(ρ)	**LFEO**	0,75 **	0,75 **	0,69 **	0,62 **	1				
	LFEC	0,69 **	0,74 **	0,65 **	0,65 **	0,79 **	1			
	RR	0,66 **	0,62 **	0,66 **	0,53 **	0,58 **	0,60 **	1		
	RL	0,76 **	0,70 **	0,72 **	0,48 **	0,53 **	0,53 **	0,80 **	1	
	RC	0,61 **	0,60 **	0,56 **	0,51 **	0,49 **	0,60 **	0,71 **	0,74 **	1

		Right Multifudus								
		SEO	**SEC**	**RFEO**	**RFEC**	**LFEO**	**LFEO**	**RR**	**RL**	**RC**
	SEO	1								
	SEC	0,94 **	1							
	RFEO	0,74 **	0,71 **	1						
	RFEC	0,67 **	0,70 **	0,75 **	1					
(ρ)	**LFEO**	0,59 **	0,60 **	0,53 **	0,58 **	1				
	LFEC	0,63 **	0,66 **	0,31	0,41 **	0,68 **	1			
	RR	0,66 **	0,71 **	0,46 **	0,33 **	0,58 **	0,47 **	1		
	RL	0,71 **	0,73 **	0,69 **	0,56 **	0,62 **	0,44 **	0,80 **		
	RC	0,76 **	0,75 **	0,55 **	0,34 **	0,50 **	0,53 **	0,81 **	0,74 **	1

						Left Multifudus				
		SEO	**SEC**	**RFEO**	**RFEC**	**LFEO**	**LFEO**	**RR**	**RL**	**RC**
(ρ)	**SEO**	1								
	SEC	0,96 **	1							
	RFEO	0,84 **	0,84 **	1						
	RFEC	0,58 **	0,55 **	0,79 **	1					
	LFEO	0,87 **	0,83 **	0,78 **	0,67 **	1				
	LFEC	0,78 **	0,80 **	0,72 **	0,61 **	0,83 **	1			
	RR	0,83 **	0,86 **	0,79 **	0,60 **	0,78 **	0,78 **	1		
	RL	0,84 **	0,76 **	0,81 **	0,69 **	0,80 **	0,69 **	0,76 **	1	
	RC	0,72 **	0,76 **	0,67 **	0,49 **	0,63 **	0,64 **	0,78 **	0,74 **	1

E

Appendix E

In this chapter, spearman correlation coefficient (ϱ) between muscles for each task performed.

Table E 1-7 – Correlation coefficient (ρ) between each task, during the performance of the task in evaluation. **p-value < 0,05

RFEO									
		ReL	**ReR**	**OL**	**OR**	**IL**	**IR**	**ML**	**MR**
(ρ)	**ReL**	1							
	ReR	0,68 **	1						
	OL	0,43 **	0,24	1					
	OR	0,24	0,16	0,56 **	1				
	IL	0,06	0,19	0,07	0,04	1			
	IR	-0,14	0,07	0,11	0,14	0,69 **	1		
	ML	-0,03	0,19	-0,03	0,04	0,73 **	0,51 **	1	
	MR	0,39 **	0,36 **	0,13	-0,05	0,50 **	0,28	0,65 **	1

RFEC									
		ReL	**ReR**	**OL**	**OR**	**IL**	**IR**	**ML**	**MR**
(ρ)	**ReL**	1							
	ReR	0,73 **	1						
	OL	0,64 **	0,53 **	1					
	OR	0,39 **	0,29	0,73 **	1				
	IL	0,27	0,32 **	0,30	0,23	1			
	IR	0,11	0,23	0,30	0,31	0,69 **	1		
	ML	0,24	0,34 **	0,26	0,16	0,59 **	0,53 **	1	
	MR	0,57 **	0,46 **	0,54 **	0,24	0,53 **	0,47 **	0,61 **	1

LFEO									
		ReL	**ReR**	**OL**	**OR**	**IL**	**IR**	**ML**	**MR**
(ρ)	**ReL**	1							
	ReR	0,64 **	1						
	OL	0,39 **	0,40 **	1					
	OR	0,19	0,27	0,64 **	1				
	IL	0,02	0,30	0,23	0,12	1			
	IR	-0,07	0,15	0,22	0,09	0,44 **	1		
	ML	0,06	0,22	0,17	0,10	0,36 **	0,46 **	1	
	MR	-0,03	0,16	0,16	-0,16	0,18	0,55 **	0,38 **	1

LFEC									
		ReL	**ReR**	**OL**	**OR**	**IL**	**IR**	**ML**	**MR**
(ρ)	**ReL**	1							
	ReR	0,62 **	1						
	OL	0,42 **	0,42 **	1					
	OR	0,15	0,23	0,60 **	1				
	IL	0,08	0,27	0,26	0,17	1			
	IR	0,10	0,28	0,12	0,19	0,39 **	1		
	ML	0,19	0,27	0,07	0,07	0,35 **	0,41 **	1	
	MR	0,16	0,32 **	0,31	0,19	0,41 **	0,63 **	0,39 **	1

RR									
		ReL	**ReR**	**OL**	**OR**	**IL**	**IR**	**ML**	**MR**
(ρ)	**ReL**	1							
	ReR	0,66 **	1						
	OL	0,42 **	0,31	1					
	OR	0,35 **	0,21	0,60 **	1				
	IL	0,00	0,17	0,08	-0,05	1			
	IR	-0,04	0,16	0,16	0,03	0,66 **	1		
	ML	0,31	0,39 **	0,34 **	0,21	0,68 **	0,60 **	1	
	MR	0,13	0,27	0,30	0,07	0,50 **	0,58 **	0,57 **	1

RL									
		ReL	**ReR**	**OL**	**OR**	**IL**	**IR**	**ML**	**MR**
(ρ)	**ReL**	1							
	ReR	0,56 **	1						
	OL	0,46 **	0,24	1					
	OR	0,26	0,13	0,65 **	1				
	IL	-0,04	0,12	0,06	0,09	1			
	IR	0,01	0,13	0,07	0,08	0,64 **	1		
	ML	0,29	0,22	0,15	0,11	0,63 **	0,58 **	1	
	MR	0,29	0,26	0,26	0,16	0,42 **	0,59 **	0,65 **	1

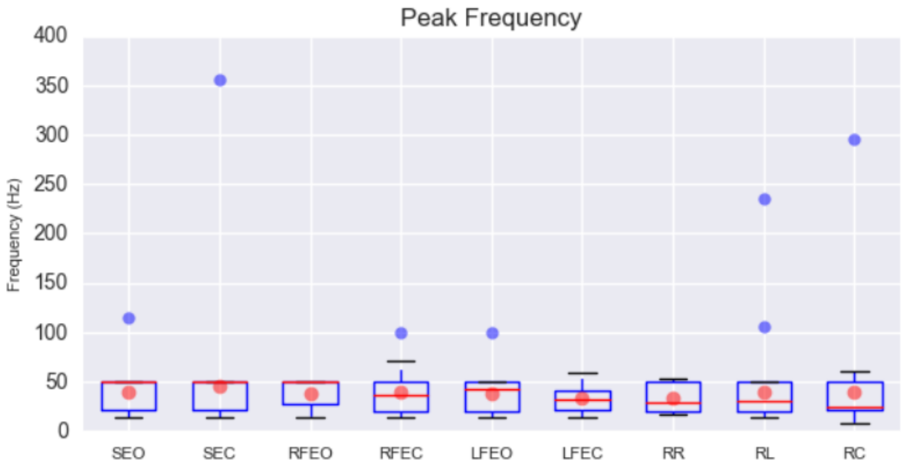
RC									
		ReL	**ReR**	**OL**	**OR**	**IL**	**IR**	**ML**	**MR**
(ρ)	**ReL**	1							
	ReR	0,58 **	1						
	OL	0,50 **	0,35 **	1					
	OR	0,40 **	0,18	0,72 **	1				
	IL	-0,11	-0,04	-0,01	0,21	1			
	IR	0,02	0,14	0,14	0,13	0,62 **	1		
	ML	0,15	0,21	0,16	0,25	0,58 **	0,47 **	1	
	MR	0,30	0,28	0,44 **	0,31	0,41 **	0,61 **	0,58 **	1

F

Appendix F

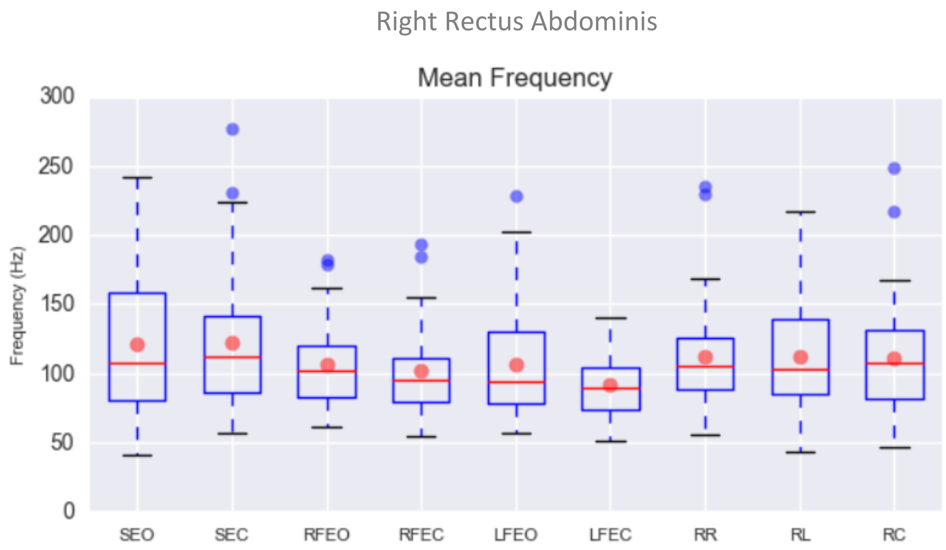
In this chapter the analysis of EMG frequency for each muscle and for each range of frequency, along the nine tasks, for a group of healthy subjects will be presented.

Right Rectus Abdominis



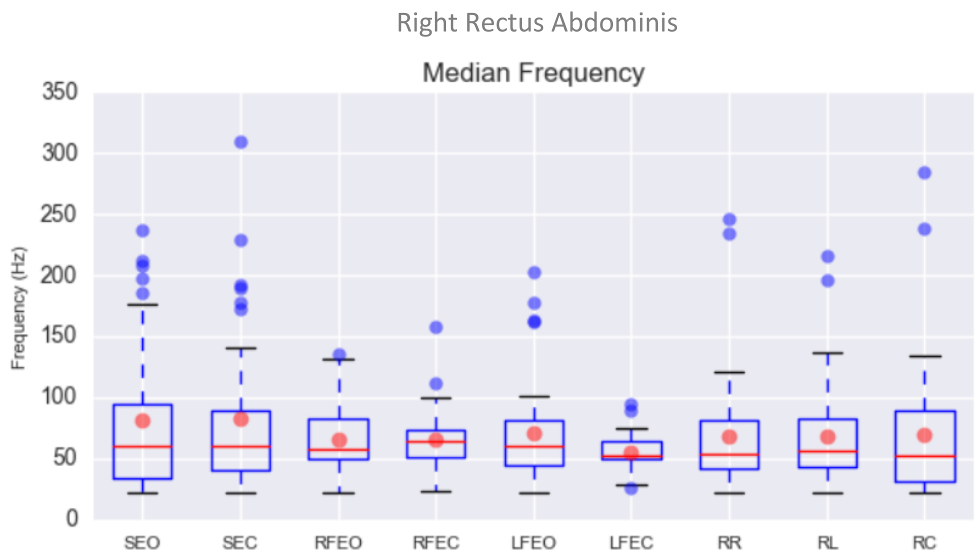
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.8998	–							
RFEO	0.8310	0.9794	–						
RFEC	0.9425	0.6308	0.7842	–					
LFEO	0.3133	0.1018	0.2835	0.5128	–				
LFEC	0.0388	0.0447	0.0363	0.0837	0.1130	–			
RR	0.1010	0.0616	0.0383	0.1610	0.4456	0.7654	–		
RL	0.0613	0.0544	0.1269	0.2208	0.3924	0.9052	0.8285	–	
RC	0.1823	0.2546	0.1060	0.0872	0.8204	0.8823	0.7449	0.9463	–

Figure F.1 – Boxplot representation and p-values between tasks for peak frequency of right Rectus Abdominis.



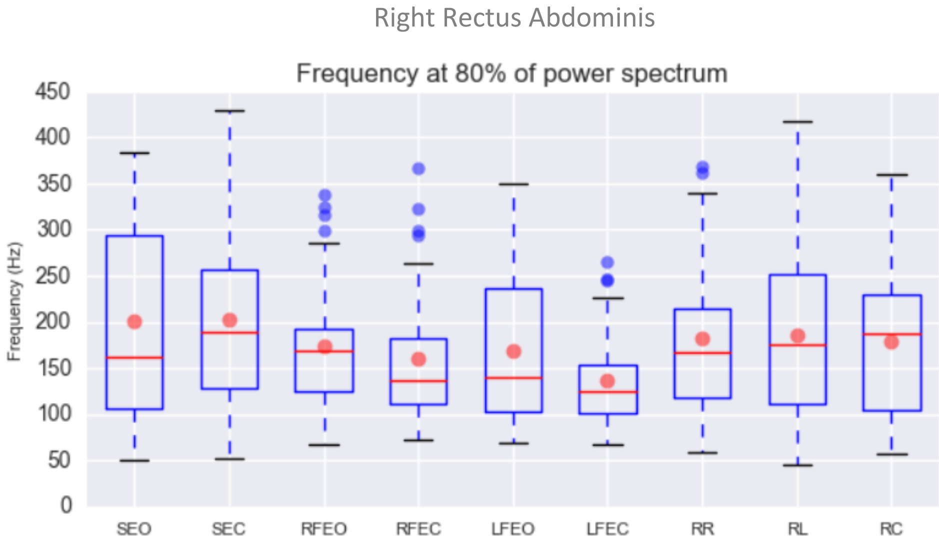
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.4766	–							
RFEO	0.1803	0.0111	–						
RFEC	0.0170	0.0034	0.0913	–					
LFEO	0.0198	0.0170	0.3793	0.5485	–				
LFEC	0.0008	0.0001	0.0040	0.0125	0.0084	–			
RR	0.3218	0.0741	0.4766	0.2041	0.2764	0.0011	–		
RL	0.1992	0.0635	0.7802	0.2142	0.1896	0.0007	0.6653	–	
RC	0.2194	0.0787	0.9889	0.3083	0.3286	0.0022	0.5959	0.9333	–

Figure F.2 – Boxplot representation and p-values between tasks for mean frequency of right Rectus Abdominis.



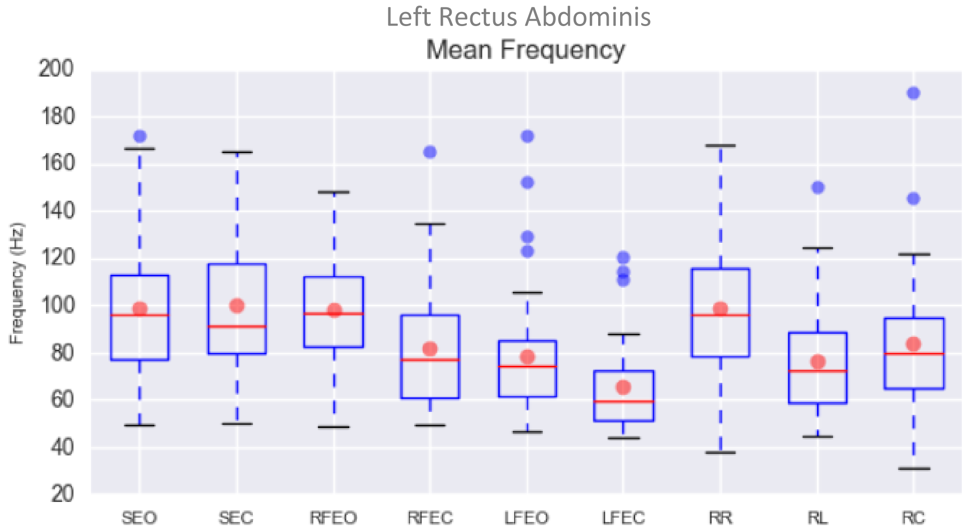
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.9047	–							
RFEO	0.2734	0.0811	–						
RFEC	0.2671	0.2159	0.7294	–					
LFEO	0.0854	0.2617	0.8327	0.8444	–				
LFEC	0.0353	0.0287	0.0267	0.0048	0.0245	–			
RR	0.0896	0.0493	0.2067	0.2202	0.1256	0.2119	–		
RL	0.0593	0.0636	0.0937	0.4166	0.7954	0.0912	0.9922	–	
RC	0.0825	0.0456	0.0700	0.1750	0.7685	0.2166	0.9455	0.6810	–

Figure F.3 – Boxplot representation and p-values between tasks for median frequency of right Rectus Abdominis.



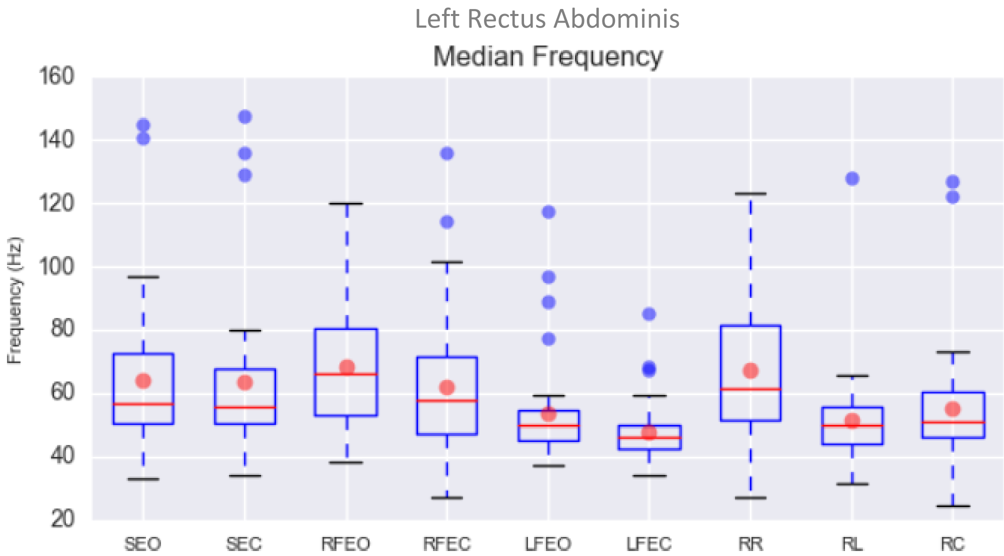
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.4818	–							
RFEO	0.1390	0.0071	–						
RFEC	0.0232	0.0061	0.0613	–					
LFEO	0.0316	0.0357	0.3252	0.6657	–				
LFEC	0.0006	0.0001	0.0024	0.0039	0.0020	–			
RR	0.3150	0.0702	0.5862	0.1721	0.2964	0.0030	–		
RL	0.2496	0.1148	0.6755	0.2204	0.3384	0.0020	0.8675	–	
RC	0.1714	0.1428	0.7885	0.1943	0.3426	0.0011	0.7011	0.8092	–

Figure F.4 – Boxplot representation and p-values between tasks for frequency at 80% of power spectrum of right Rectus Abdominis.



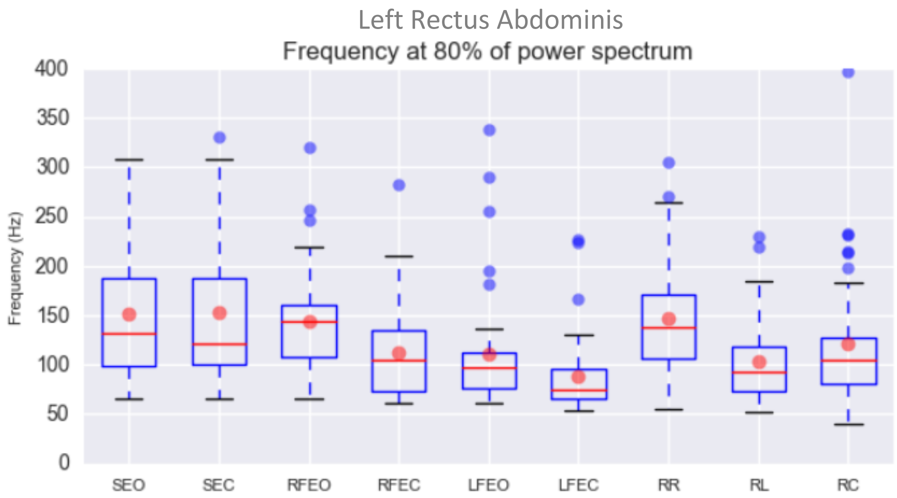
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.0836	–							
RFEO	0.5672	0.4428	–						
RFEC	0.2643	0.0811	0.0697	–					
LFEO	0.1391	0.3286	0.0811	0.0017	–				
LFEC	0.4345	0.9889	0.7909	0.0146	0.1587	–			
RR	0.8670	0.3150	0.8890	0.3498	0.2247	0.4511	–		
RL	0.0074	0.1248	0.0065	0.0087	0.1085	0.0811	0.0048	–	
RC	0.0940	0.5959	0.3150	0.0559	0.7588	0.7802	0.1181	0.0887	–

Figure F.5 – Boxplot representation and p-values between tasks for mean frequency of left Rectus Abdominis.



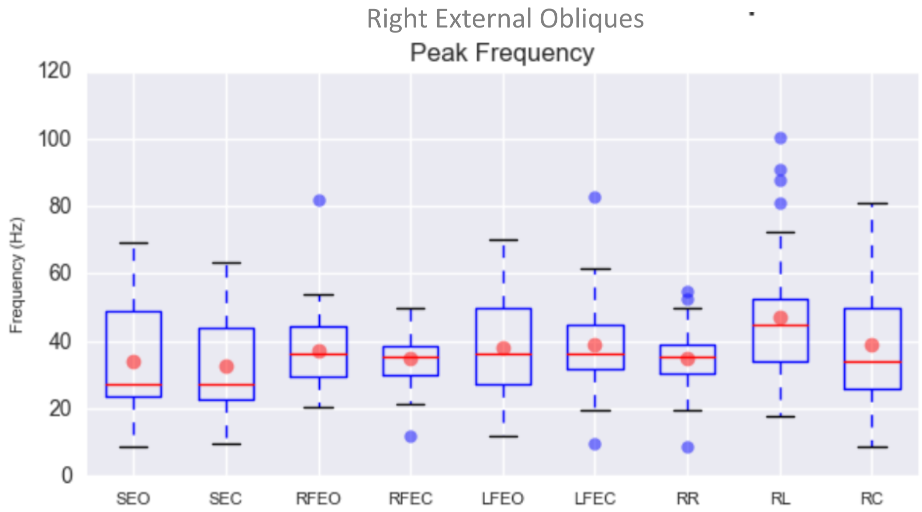
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.8880	–							
RFEO	0.0365	0.0372	–						
RFEC	0.0883	0.0762	0.7224	–					
LFEO	0.0043	0.0013	0.2025	0.3083	–				
LFEC	0.0008	0.0014	0.0083	0.0482	0.1684	–			
RR	0.6739	0.8014	0.0521	0.0644	0.0174	0.0039	–		
RL	0.0222	0.0592	0.9940	0.9159	0.7002	0.3345	0.0193	–	
RC	0.1907	0.1311	0.1660	0.1445	0.0278	0.0067	0.6017	0.1081	–

Figure F.6 – Boxplot representation and p-values between tasks for median frequency of left Rectus Abdominis.



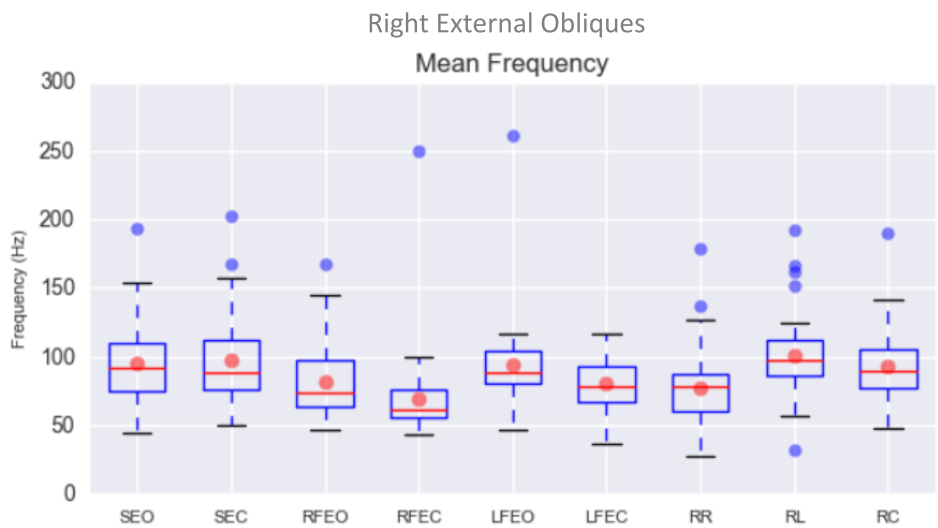
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.1330	–							
RFEO	0.7855	0.4746	–						
RFEC	0.4680	0.1466	0.0749	–					
LFEO	0.1843	0.4068	0.0605	0.0006	–				
LFEC	0.5245	0.9333	0.7859	0.0187	0.0549	–			
RR	0.7535	0.3017	0.6374	0.3792	0.2577	0.4722	–		
RL	0.0087	0.1230	0.0035	0.0066	0.0763	0.0899	0.0029	–	
RC	0.1196	0.8860	0.2548	0.0363	0.7271	0.6908	0.1530	0.0883	–

Figure F.7 – Boxplot representation and p-values between tasks for frequency at 80% of power spectrum of left Rectus Abdominis.



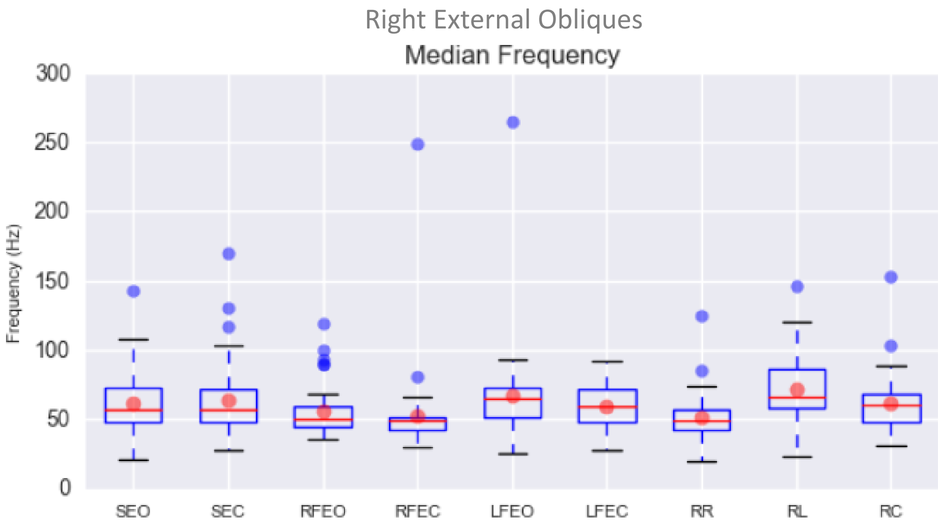
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.6627	–							
RFEO	0.2474	0.0434	–						
RFEC	0.8465	0.6889	0.2546	–					
LFEO	0.2637	0.4374	0.0066	0.0481	–				
LFEC	0.0122	0.0270	0.0003	0.0017	0.0980	–			
RR	0.9493	0.6734	0.1728	0.3691	0.6166	0.0717	–		
RL	0.2450	0.4329	0.0389	0.1841	0.8369	0.0803	0.4059	–	
RC	0.5385	0.8375	0.1468	0.6878	0.4912	0.0223	0.8986	0.5433	–

Figure F.8 – Boxplot representation and p-values between tasks for peak frequency of right External Obliques.



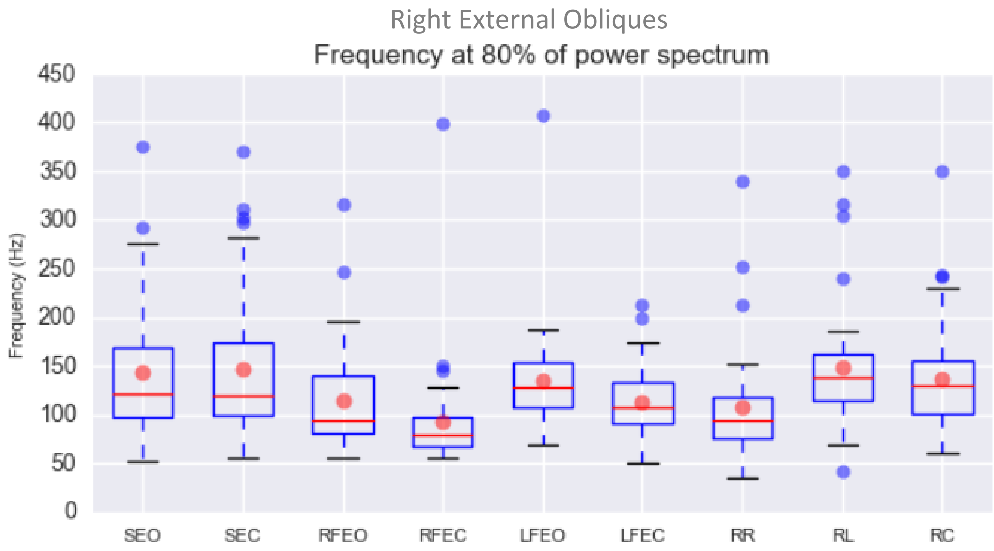
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.8342	–							
RFEO	0.7695	0.5767	–						
RFEC	0.0002	0.0001	0.0001	–					
LFEO	0.0000	0.0000	0.0000	0.1896	–				
LFEC	0.0000	0.0000	0.0000	0.0000	0.0000	–			
RR	0.5863	0.5485	0.8451	0.0005	0.0000	0.0000	–		
RL	0.0000	0.0000	0.0000	0.1714	0.8451	0.0004	0.0000	–	
RC	0.0019	0.0009	0.0006	0.5672	0.0524	0.0000	0.0006	0.0541	–

Figure F.9 – Boxplot representation and p-values between tasks for mean frequency of right External Obliques.



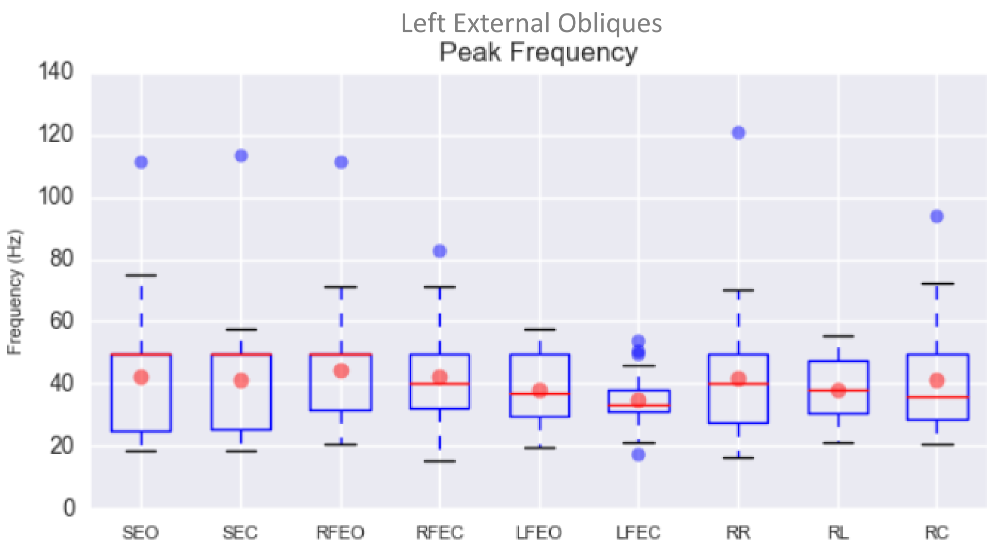
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.4428	–							
RFEO	0.0333	0.0148	–						
RFEC	0.4221	0.5280	0.0111	–					
LFEO	0.0003	0.0001	0.0000	0.0001	–				
LFEC	0.0000	0.0000	0.0000	0.0000	0.0005	–			
RR	0.2611	0.1847	0.5623	0.2765	0.0001	0.0000	–		
RL	0.0001	0.0001	0.0000	0.0004	0.6439	0.0102	0.0000	–	
RC	0.0022	0.0020	0.0000	0.0109	0.1633	0.0003	0.0000	0.1139	–

Figure F.10 – Boxplot representation and p-values between tasks for median frequency of right External Obliques.



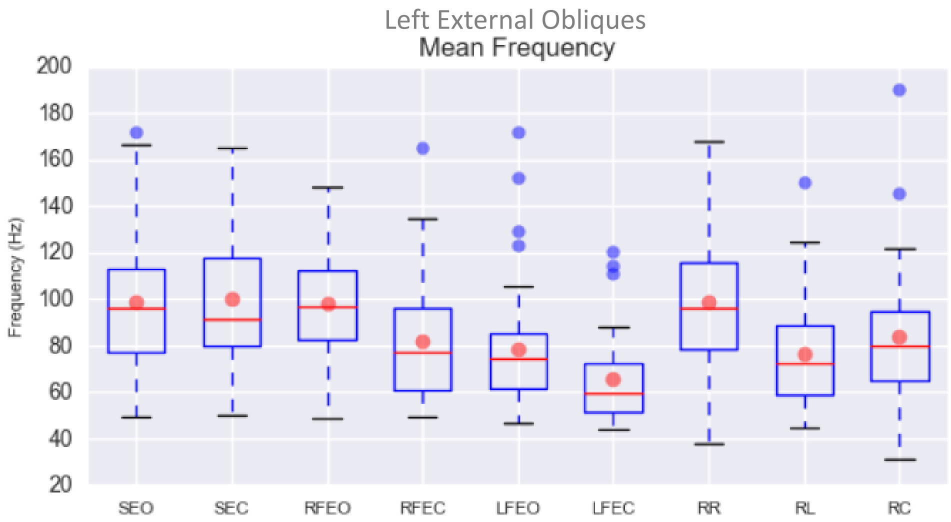
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.4863	–							
RFEO	0.6015	0.4551	–						
RFEC	0.0004	0.0003	0.0003	–					
LFEO	0.0001	0.0001	0.0002	0.3169	–				
LFEC	0.0000	0.0000	0.0000	0.0000	0.0000	–			
RR	0.4818	0.5281	0.6056	0.0002	0.0000	0.0000	–		
RL	0.0000	0.0000	0.0000	0.1895	0.7607	0.0011	0.0000	–	
RC	0.0050	0.0083	0.0049	0.5908	0.0585	0.0000	0.0025	0.0910	–

Figure F.11 – Boxplot representation and p-values between tasks for frequency at 80% of power spectrum of right External Obliques.



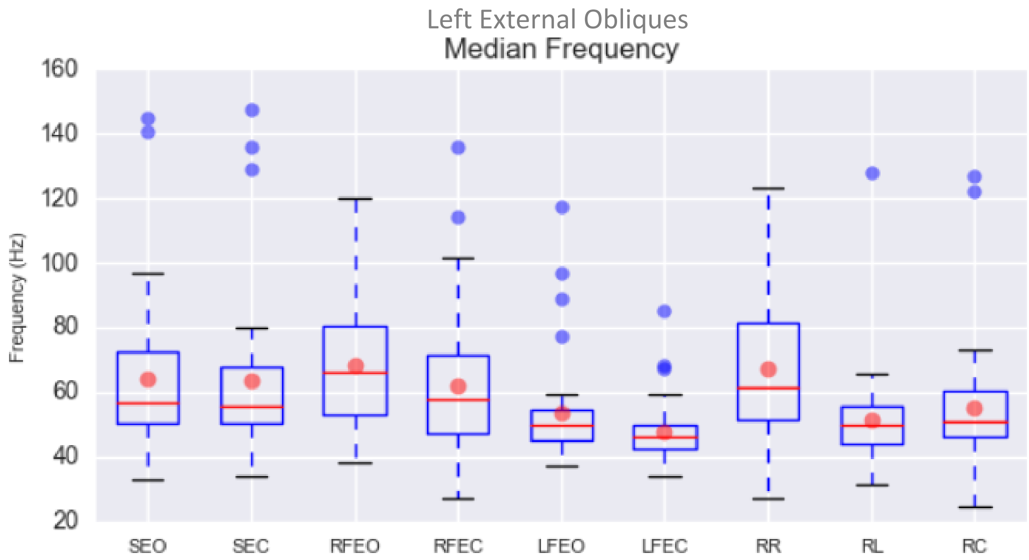
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.3976	–							
RFEO	0.2575	0.0373	–						
RFEC	0.3182	0.2086	0.3219	–					
LFEO	0.0641	0.0055	0.5122	0.2966	–				
LFEC	0.0128	0.0028	0.2678	0.0445	0.5211	–			
RR	0.3123	0.0663	0.7428	0.6938	0.3318	0.1393	–		
RL	0.0003	0.0004	0.0108	0.0010	0.0025	0.0325	0.0004	–	
RC	0.0252	0.0209	0.7504	0.2360	0.7712	0.5410	0.5943	0.0101	–

Figure F.12 – Boxplot representation and p-values between tasks for peak frequency of left External Obliques.



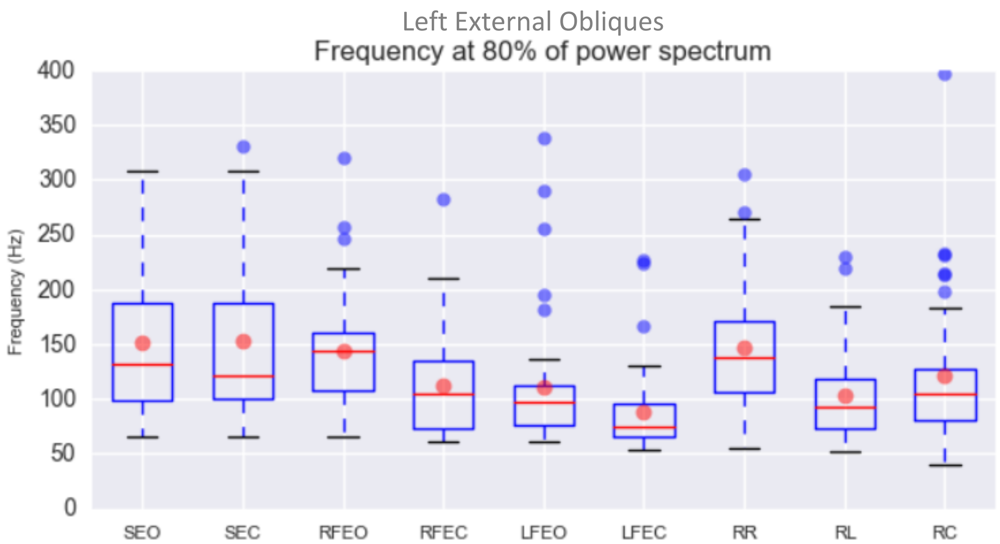
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.2091	–							
RFEO	0.0000	0.0000	–						
RFEC	0.0000	0.0000	0.0002	–					
LFEO	0.9444	0.8670	0.0002	0.0000	–				
LFEC	0.0010	0.0014	0.7377	0.0002	0.0005	–			
RR	0.0001	0.0001	0.2889	0.0430	0.0000	0.1025	–		
RL	0.0363	0.1671	0.0002	0.0000	0.0198	0.0001	0.0000	–	
RC	0.6056	0.4428	0.0087	0.0001	0.4941	0.0475	0.0000	0.0184	–

Figure F.13 – Boxplot representation and p-values between tasks for mean frequency of left External Obliques.



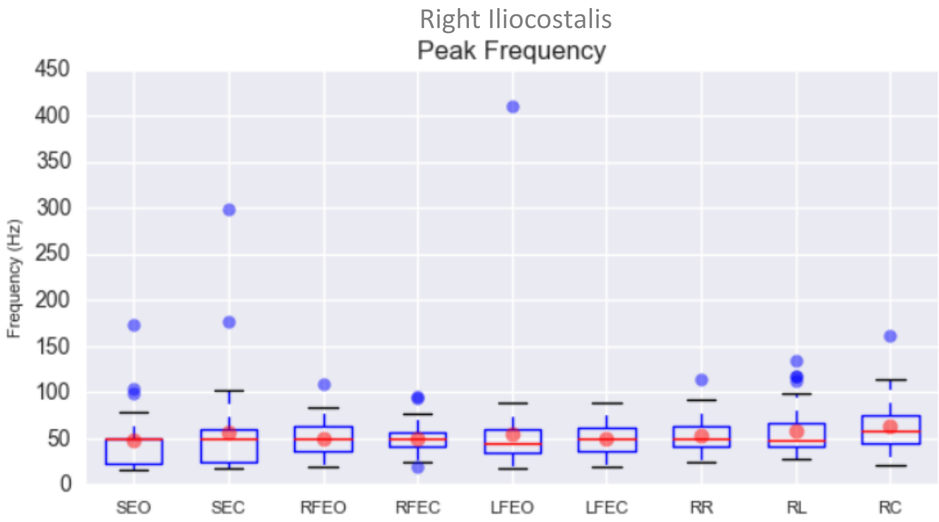
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.1168	–							
RFEO	0.0140	0.0025	–						
RFEC	0.0010	0.0005	0.0109	–					
LFEO	0.0071	0.0351	0.0005	0.0000	–				
LFEC	0.9711	0.9133	0.0519	0.0001	0.1007	–			
RR	0.0014	0.0003	0.2827	0.4367	0.0001	0.0049	–		
RL	0.0001	0.0030	0.0001	0.0000	0.0187	0.0024	0.0000	–	
RC	0.2457	0.8674	0.0143	0.0010	0.0869	0.9166	0.0001	0.0008	–

Figure F.14 – Boxplot representation and p-values between tasks for median frequency of left External Obliques.



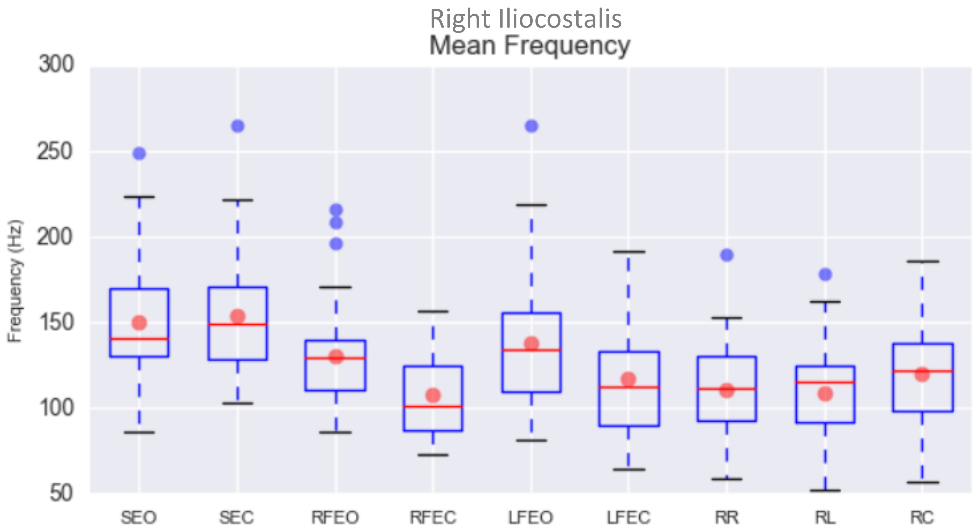
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.2521	–							
RFEO	0.0000	0.0000	–						
RFEC	0.0000	0.0000	0.0003	–					
LFEO	0.8560	0.9711	0.0001	0.0000	–				
LFEC	0.0088	0.0177	0.3907	0.0001	0.0017	–			
RR	0.0002	0.0002	0.4643	0.0515	0.0000	0.0475	–		
RL	0.2142	0.4772	0.0002	0.0000	0.0339	0.0002	0.0000	–	
RC	0.4909	0.3149	0.0049	0.0000	0.3497	0.0817	0.0000	0.0756	–

Figure F.15 – Boxplot representation and p-values between tasks for frequency at 80% of power spectrum of left External Obliques.



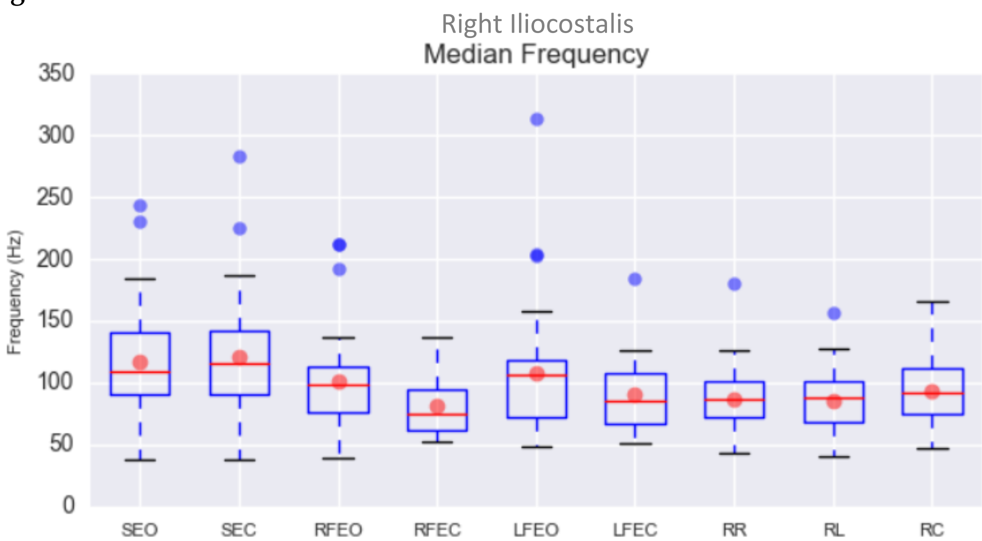
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.7094	–							
RFEO	0.3993	0.8209	–						
RFEC	0.2832	0.6406	0.8570	–					
LFEO	0.6357	0.9004	0.4462	0.2832	–				
LFEC	0.1765	0.5194	0.9412	0.7058	0.1736	–			
RR	0.0796	0.2131	0.3296	0.3961	0.1022	0.2739	–		
RL	0.1015	0.1125	0.1698	0.3608	0.1594	0.2612	0.5194	–	
RC	0.0016	0.0162	0.0036	0.0110	0.0010	0.0055	0.0702	0.1976	–

Figure F.16 – Boxplot representation and p-values between tasks for peak frequency of right Iliocostalis.



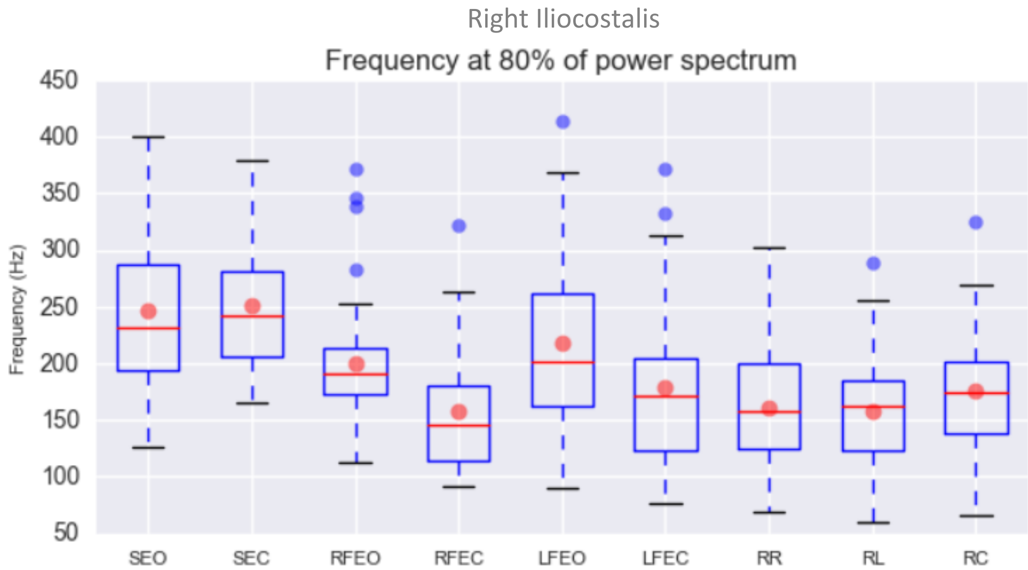
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.2468	–							
RFEO	0.0002	0.0001	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0006	0.0012	0.5863	0.0000	–				
LFEC	0.0000	0.0000	0.0541	0.2411	0.0000	–			
RR	0.0000	0.0000	0.0015	0.3869	0.0000	0.5300	–		
RL	0.0000	0.0000	0.0010	0.4511	0.0000	0.3018	0.6755	–	
RC	0.0000	0.0000	0.1546	0.0019	0.0039	0.1714	0.0003	0.0001	–

Figure F.17 – Boxplot representation and p-values between tasks for mean frequency of right Iliocostalis.



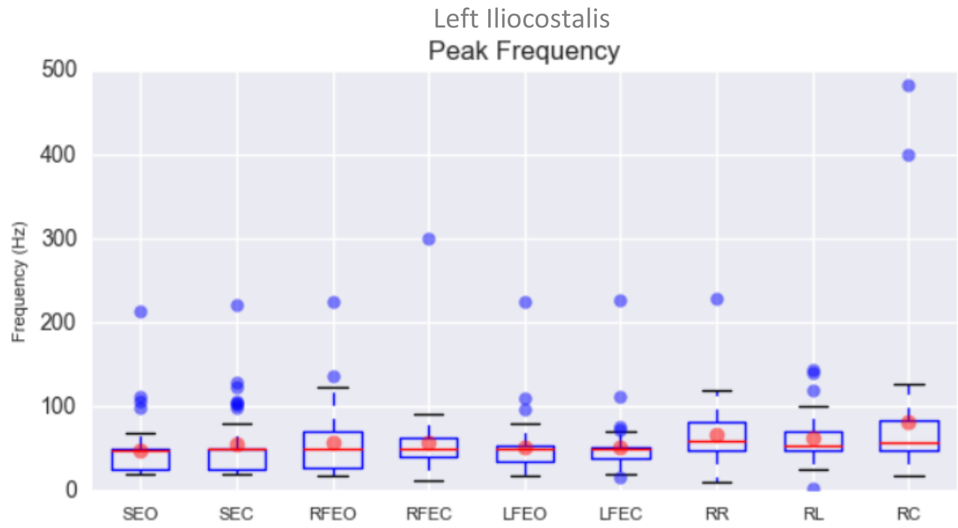
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.6770	–							
RFEO	0.0065	0.0061	–						
RFEC	0.0000	0.0000	0.0001	–					
LFEO	0.0044	0.0127	0.9711	0.0003	–				
LFEC	0.0001	0.0000	0.1546	0.2978	0.0024	–			
RR	0.0001	0.0002	0.0274	0.2065	0.0485	0.6740	–		
RL	0.0000	0.0001	0.0237	0.3031	0.0098	0.7115	0.9421	–	
RC	0.0018	0.0005	0.4303	0.0076	0.2582	0.1505	0.0012	0.0006	–

Figure F.18 – Boxplot representation and p-values between tasks for meadian frequency of right Iliocostalis.



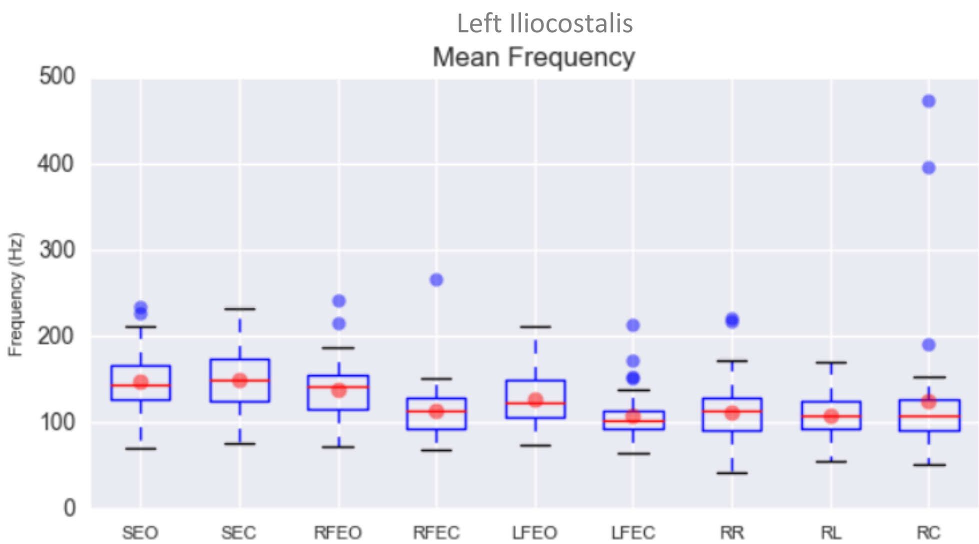
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.6167	–							
RFEO	0.0001	0.0000	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0006	0.0019	0.4595	0.0000	–				
LFEC	0.0000	0.0000	0.0940	0.1826	0.0001	–			
RR	0.0000	0.0000	0.0018	0.3717	0.0000	0.3574	–		
RL	0.0000	0.0000	0.0007	0.4723	0.0000	0.1371	0.9479	–	
RC	0.0000	0.0000	0.0586	0.0062	0.0021	0.4553	0.0026	0.0004	–

Figure F.19 – Boxplot representation and p-values between tasks for frequency at 80% of power spectrum of right Iliocostalis.



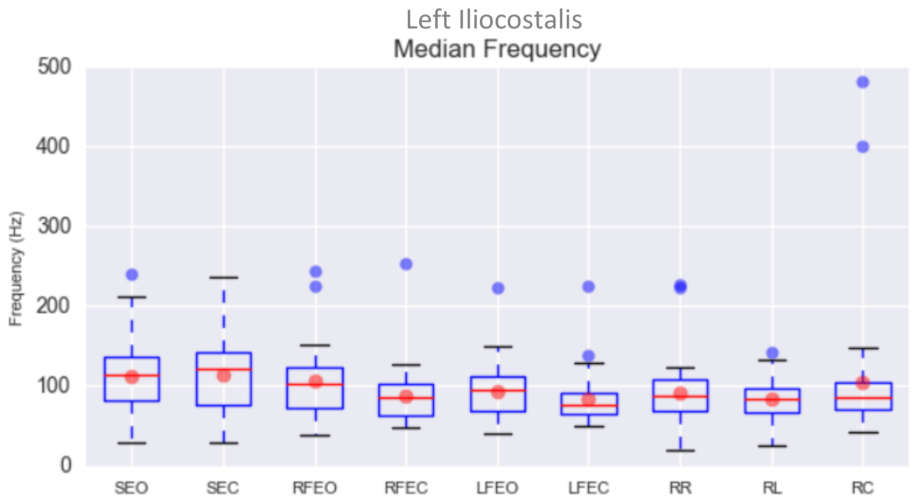
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.0582	–							
RFEO	0.0406	0.3993	–						
RFEC	0.0512	0.7956	0.7576	–					
LFEO	0.2515	0.5738	0.2473	0.0643	–				
LFEC	0.3090	0.7074	0.5980	0.1552	0.8216	–			
RR	0.0001	0.0145	0.0346	0.0510	0.0005	0.0012	–		
RL	0.0052	0.0460	0.0885	0.2254	0.0153	0.0064	0.9076	–	
RC	0.0006	0.0148	0.0096	0.0387	0.0002	0.0004	0.5176	0.4317	–

Figure F.20 – Boxplot representation and p-values between tasks for peak frequency of left Iliocostalis.



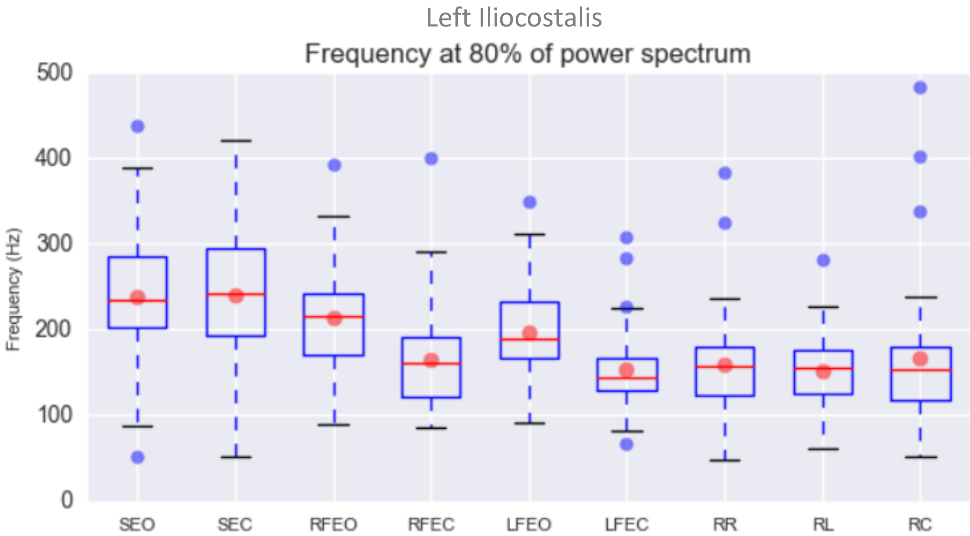
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.7063	–							
RFEO	0.0787	0.0184	–						
RFEC	0.0001	0.0000	0.0000	–					
LFEO	0.0016	0.0004	0.1391	0.0285	–				
LFEC	0.0000	0.0000	0.0000	0.2142	0.0000	–			
RR	0.0000	0.0000	0.0000	0.1803	0.0198	0.2703	–		
RL	0.0000	0.0000	0.0000	0.4941	0.0042	0.5119	0.8017	–	
RC	0.0013	0.0001	0.0002	0.1849	0.0577	0.2826	0.9777	0.6252	–

Figure F.21 – Boxplot representation and p-values between tasks for mean frequency of left Iliocostalis.



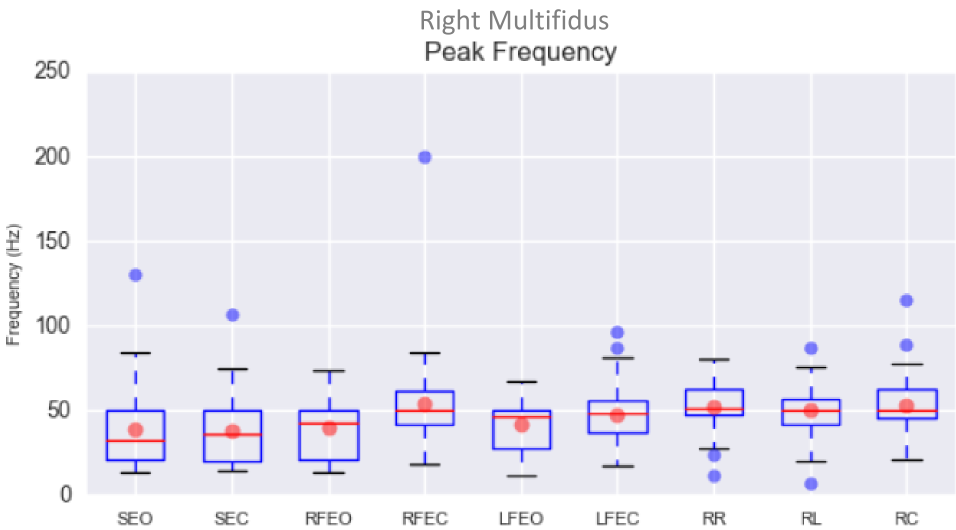
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.5661	–							
RFEO	0.4335	0.0981	–						
RFEC	0.0028	0.0014	0.0004	–					
LFEO	0.0061	0.0032	0.0643	0.3773	–				
LFEC	0.0001	0.0000	0.0001	0.1490	0.0012	–			
RR	0.0029	0.0001	0.0011	0.5568	0.5118	0.0830	–		
RL	0.0028	0.0003	0.0004	0.8451	0.4152	0.2229	0.9249	–	
RC	0.0301	0.0043	0.0063	0.5815	0.8052	0.0985	0.5342	0.6345	–

Figure F.22 – Boxplot representation and p-values between tasks for median frequency of left Iliocostalis.



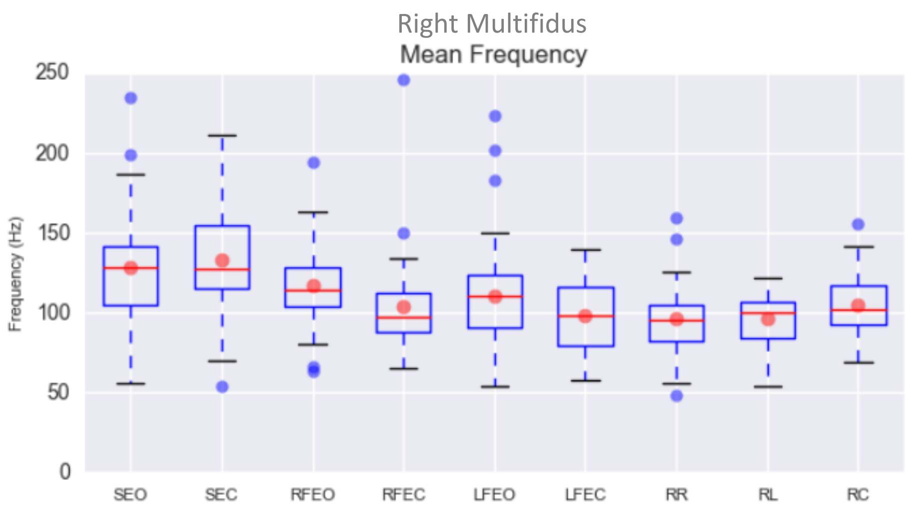
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.8561	–							
RFEO	0.0351	0.0142	–						
RFEC	0.0001	0.0000	0.0000	–					
LFEO	0.0024	0.0011	0.2411	0.0129	–				
LFEC	0.0000	0.0000	0.0000	0.2642	0.0000	–			
RR	0.0000	0.0000	0.0000	0.1247	0.0029	0.4303	–		
RL	0.0000	0.0000	0.0000	0.2671	0.0008	0.6501	0.9166	–	
RC	0.0002	0.0000	0.0000	0.0686	0.0073	0.4955	0.6846	0.5280	–

Figure F.23 – Boxplot representation and p-values between tasks for frequency at 80% of power spectrum of left Iliocostalis.



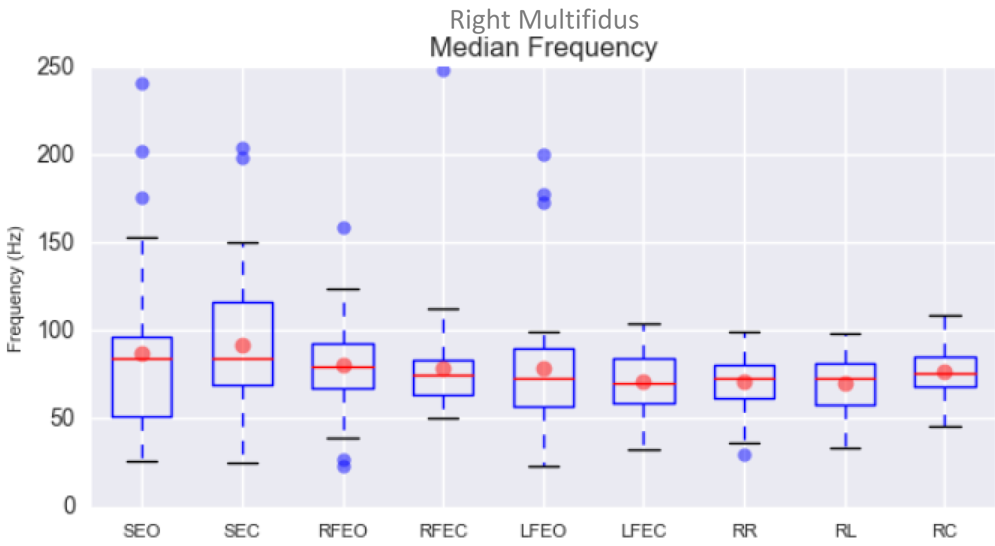
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.4651	–							
RFEO	0.2785	0.3406	–						
RFEC	0.0017	0.0006	0.0009	–					
LFEO	0.2206	0.1139	0.4421	0.0187	–				
LFEC	0.0069	0.0040	0.0414	0.0512	0.1966	–			
RR	0.0011	0.0005	0.0019	0.7003	0.0136	0.2723	–		
RL	0.0055	0.0035	0.0104	0.9561	0.0553	0.1531	0.4528	–	
RC	0.0015	0.0011	0.0032	0.6892	0.0067	0.0768	0.7131	0.2775	–

Figure F.24 – Boxplot representation and p-values between tasks for peak frequency of right Multifidus.



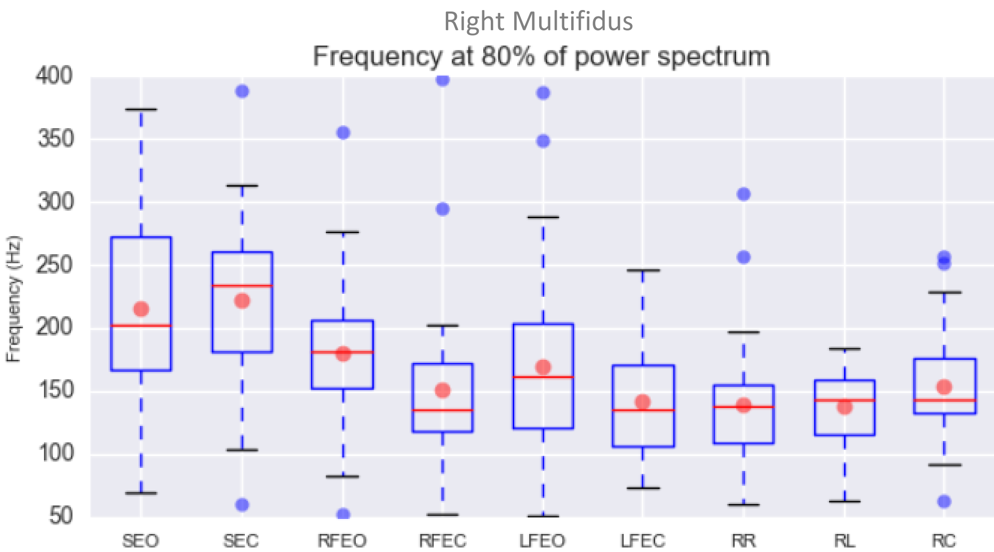
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.2194	–							
RFEO	0.0559	0.0001	–						
RFEC	0.0003	0.0000	0.0007	–					
LFEO	0.0115	0.0004	0.1629	0.2041	–				
LFEC	0.0000	0.0000	0.0007	0.1992	0.0030	–			
RR	0.0001	0.0000	0.0014	0.1992	0.0191	0.8233	–		
RL	0.0000	0.0000	0.0001	0.1055	0.0080	0.6552	0.6960	–	
RC	0.0001	0.0000	0.0120	0.2764	0.3570	0.0146	0.0295	0.0007	–

Figure F.25 – Boxplot representation and p-values between tasks for mean frequency of right Multifidus.



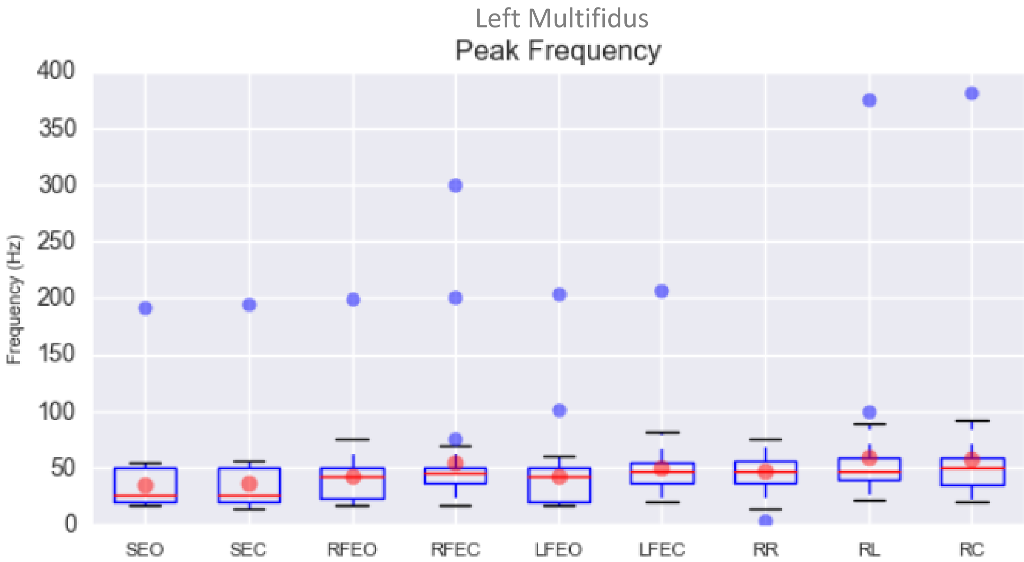
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.1038	–							
RFEO	0.6501	0.0123	–						
RFEC	0.5391	0.0131	0.0811	–					
LFEO	0.6529	0.0296	0.3532	0.4228	–				
LFEC	0.0843	0.0003	0.0099	0.0367	0.1914	–			
RR	0.2579	0.0092	0.0791	0.1673	0.3830	0.9039	–		
RL	0.0740	0.0009	0.0354	0.1189	0.2160	0.8441	0.9248	–	
RC	0.5667	0.0142	0.4125	0.6941	0.9812	0.0229	0.0501	0.0227	–

Figure F.26 – Boxplot representation and p-values between tasks for median frequency of right Multifidus.



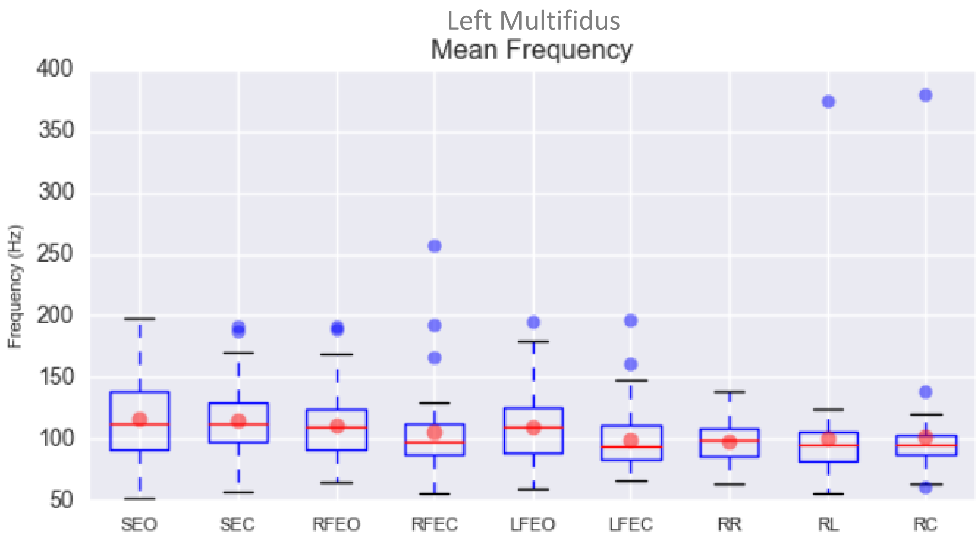
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.5767	–							
RFEO	0.0057	0.0000	–						
RFEC	0.0000	0.0000	0.0009	–					
LFEO	0.0019	0.0002	0.2702	0.0775	–				
LFEC	0.0000	0.0000	0.0018	0.3608	0.0050	–			
RR	0.0000	0.0000	0.0022	0.3183	0.0260	0.8860	–		
RL	0.0000	0.0000	0.0000	0.1566	0.0069	0.7996	0.5915	–	
RC	0.0000	0.0000	0.0082	0.3150	0.1450	0.0260	0.0430	0.0016	–

Figure F.27 – Boxplot representation and p-values between tasks for frequency at 80% of power spectrum of right Multifidus.



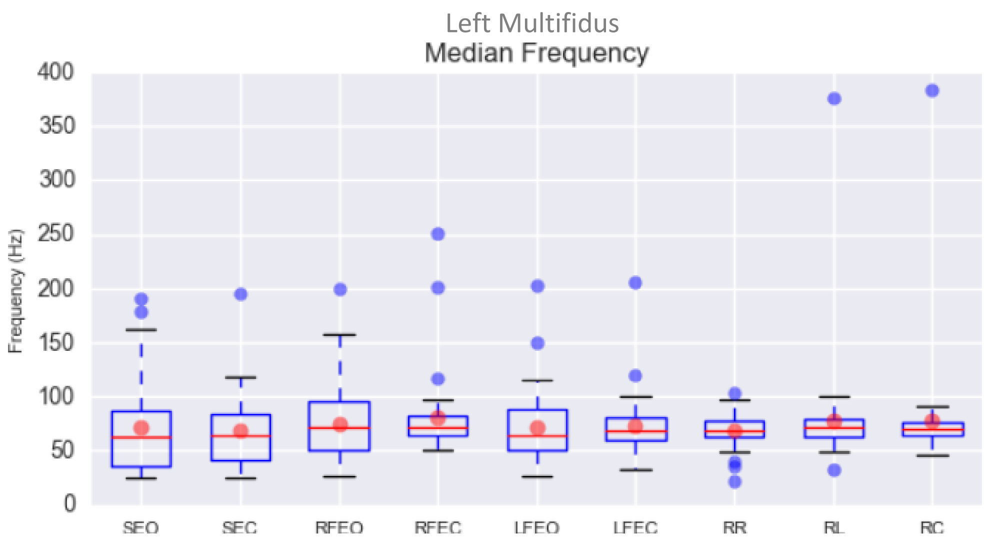
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.2316	–							
RFEO	0.0042	0.0506	–						
RFEC	0.0001	0.0012	0.0287	–					
LFEO	0.0146	0.0337	0.8852	0.0357	–				
LFEC	0.0000	0.0002	0.0096	0.4942	0.0044	–			
RR	0.0001	0.0003	0.0286	0.7414	0.0209	0.8689	–		
RL	0.0000	0.0000	0.0009	0.1102	0.0014	0.2293	0.3266	–	
RC	0.0000	0.0002	0.0108	0.5042	0.0091	0.4795	0.7123	0.6713	–

Figure F.28 – Boxplot representation and p-values between tasks for peak frequency of left Multifidus.



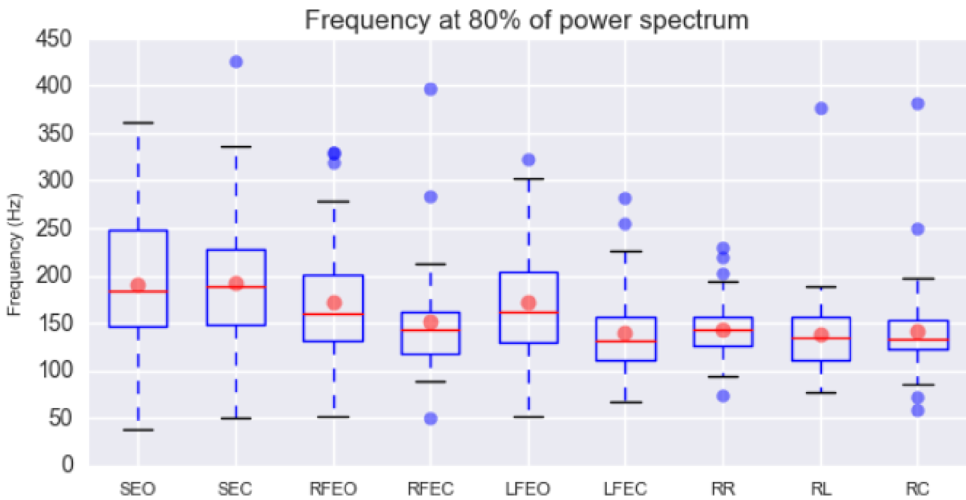
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.6056	–							
RFEO	0.5209	0.0861	–						
RFEC	0.0697	0.0402	0.0146	–					
LFEO	0.3869	0.2953	0.5209	0.1428	–				
LFEC	0.0094	0.0028	0.0098	0.0861	0.0039	–			
RR	0.0115	0.0025	0.0026	0.3150	0.0080	0.2889	–		
RL	0.0140	0.0044	0.0120	0.1671	0.0275	0.6154	0.4853	–	
RC	0.0177	0.0050	0.0164	0.1354	0.0135	0.7063	0.5959	0.9444	–

Figure F.29 – Boxplot representation and p-values between tasks for mean frequency of left Multifidus.



	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.7066	–							
RFEO	0.1296	0.0189	–						
RFEC	0.0768	0.0167	0.4601	–					
LFEO	0.5624	0.2852	0.1196	0.0982	–				
LFEC	0.3882	0.2132	0.8034	0.0808	0.6026	–			
RR	0.5029	0.2839	0.5280	0.1082	0.7376	0.7828	–		
RL	0.1264	0.1278	0.8563	0.8341	0.3495	0.3011	0.5518	–	
RC	0.2286	0.2123	0.9159	0.3346	0.3608	0.6064	0.7455	0.3660	–

Figure F.30 – Boxplot representation and p-values between tasks for median frequency of left Multifidus.

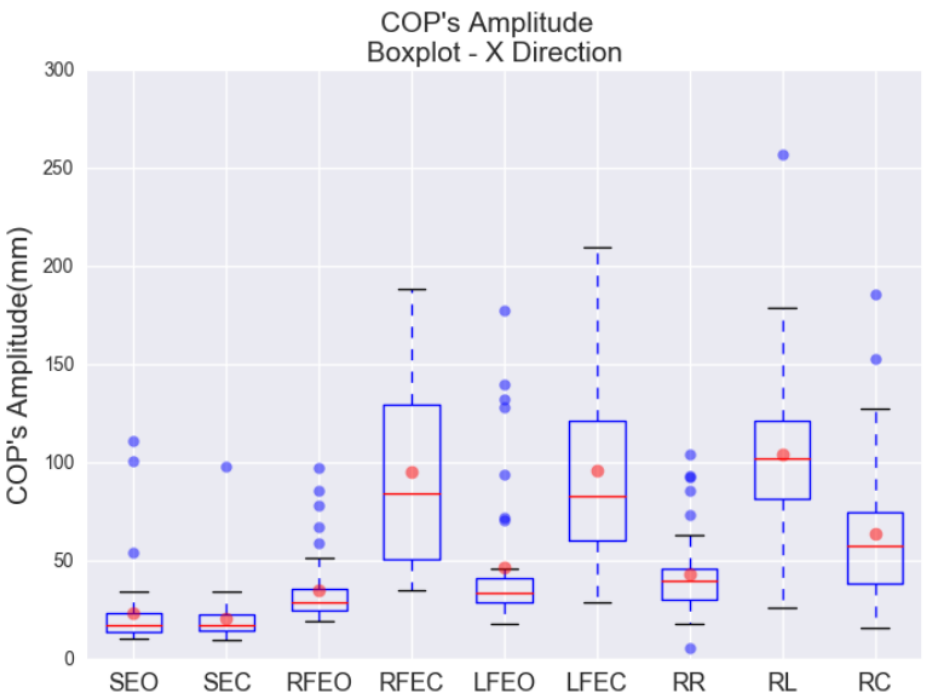


	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.6006	–							
RFEO	0.3643	0.0232	–						
RFEC	0.0083	0.0051	0.0022	–					
LFEO	0.1968	0.1180	0.7272	0.0327	–				
LFEC	0.0005	0.0007	0.0026	0.0899	0.0005	–			
RR	0.0014	0.0004	0.0015	0.3907	0.0029	0.2044	–		
RL	0.0009	0.0007	0.0036	0.0883	0.0036	0.7482	0.2044	–	
RC	0.0026	0.0013	0.0051	0.1649	0.0028	0.4683	0.3830	0.9422	–

Figure F.31 – Boxplot representation and p-values between tasks for frequency at 80% of power spectrum of left Multifidus.

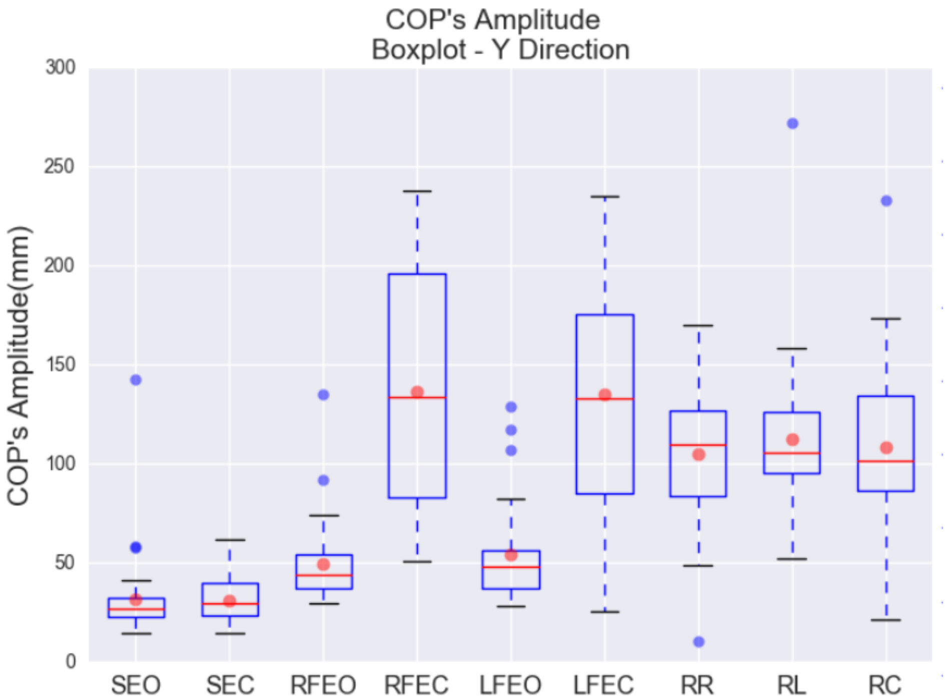
Appendix G

In this chapter, the analysis regarding COP parameters along the nine tasks, for a group of healthy subjects will be presented.



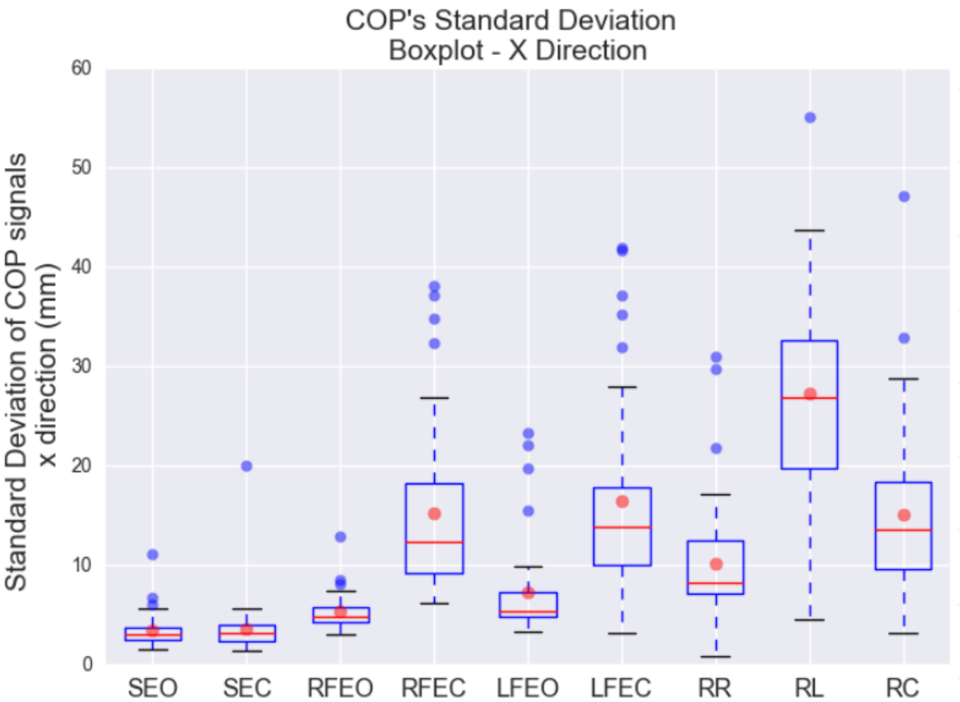
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.7802	–							
RFEO	0.0002	0.0000	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0001	0.0000	0.0074	0.0000	–				
LFEC	0.0000	0.0000	0.0000	0.9001	0.0000	–			
RR	0.0001	0.0000	0.0559	0.0000	0.4680	0.0000	–		
RL	0.0000	0.0000	0.0000	0.4183	0.0000	0.4264	0.0000	–	
RC	0.0000	0.0000	0.0000	0.0014	0.0125	0.0002	0.0019	0.0000	–

Figure G.1 – Boxplot representation and p-values between tasks for COP's Amplitude in X direction.



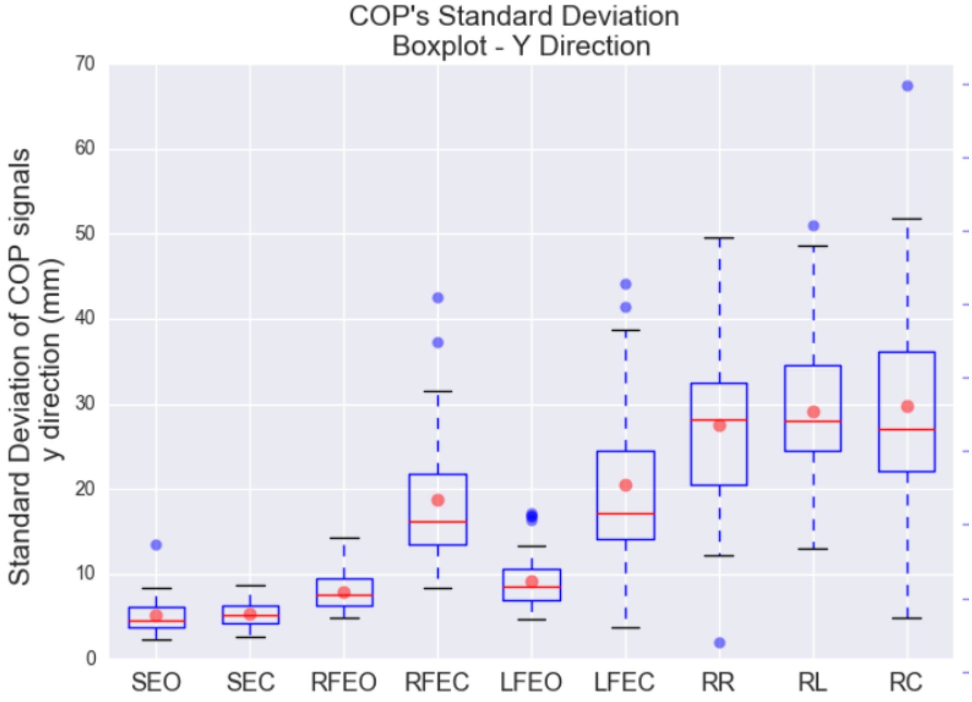
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.2889	–							
RFEO	0.0000	0.0000	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0000	0.0000	0.2142	0.0000	–				
LFEC	0.0000	0.0000	0.0000	0.9333	0.0000	–			
RR	0.0000	0.0000	0.0000	0.0048	0.0000	0.0065	–		
RL	0.0000	0.0000	0.0000	0.0339	0.0000	0.0205	0.2643	–	
RC	0.0000	0.0000	0.0000	0.0376	0.0000	0.0057	0.5672	0.2953	–

Figure G.2 – Boxplot representation and p-values between tasks for COP's Amplitude in Y direction.



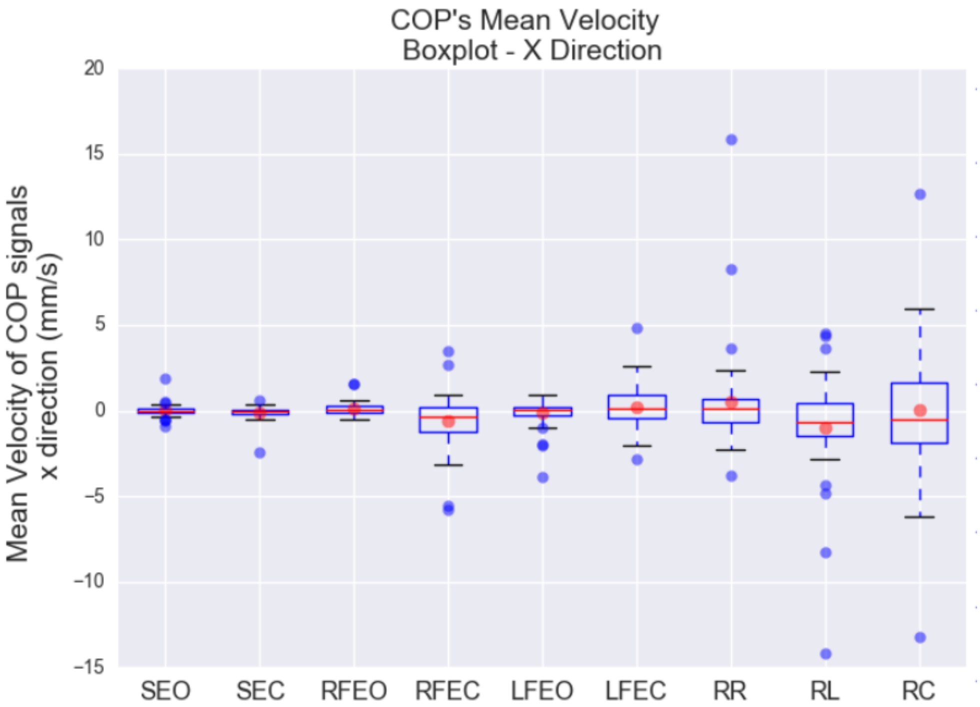
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.8780	–							
RFEO	0.0000	0.0000	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0000	0.0000	0.0046	0.0000	–				
LFEC	0.0000	0.0000	0.0000	0.8342	0.0000	–			
RR	0.0000	0.0000	0.0000	0.0044	0.0013	0.0012	–		
RL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	–	
RC	0.0000	0.0000	0.0000	0.9222	0.0000	0.5767	0.0042	0.0000	–

Figure G.3 – Boxplot representation and p-values between tasks for COP's standard deviation in X direction.



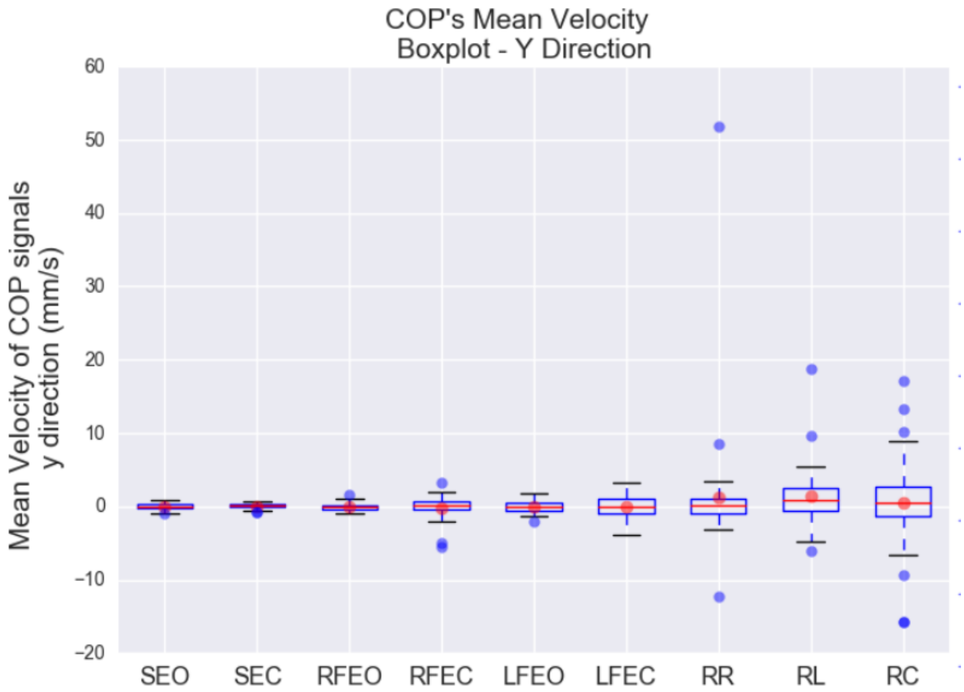
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.2525	–							
RFEO	0.0000	0.0000	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0000	0.0000	0.0811	0.0000	–				
LFEC	0.0000	0.0000	0.0000	0.4766	0.0000	–			
RR	0.0000	0.0000	0.0000	0.0002	0.0000	0.0042	–		
RL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004	0.2826	–	
RC	0.0000	0.0000	0.0000	0.0002	0.0000	0.0003	0.2041	0.6252	–

Figure G.4 – Boxplot representation and p-values between tasks for COP's standard deviation in Y direction.



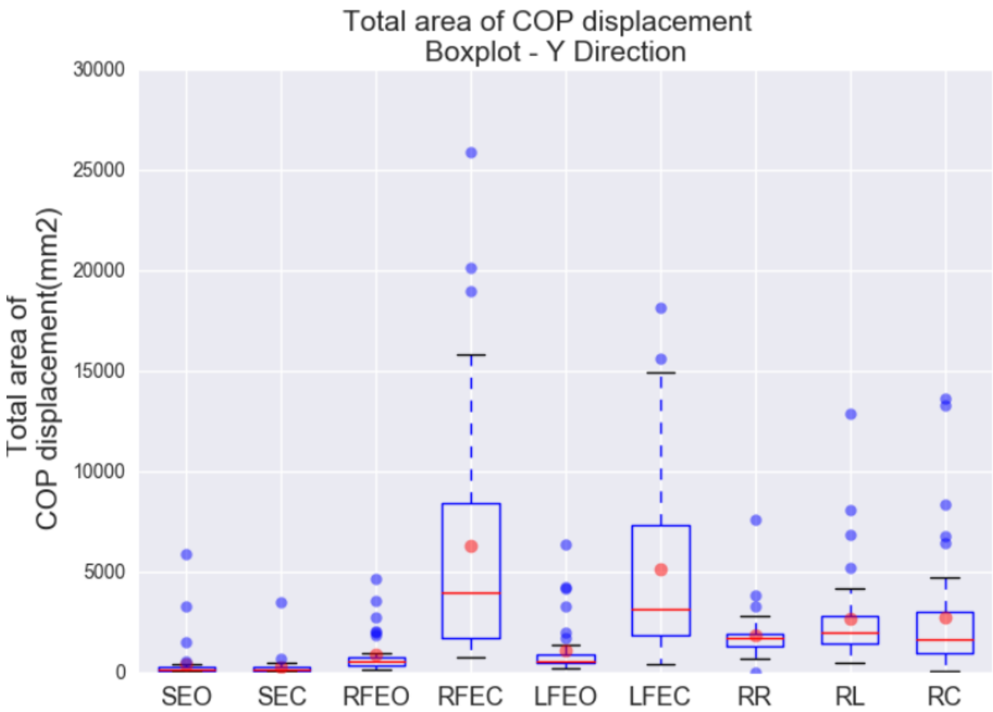
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.5209	–							
RFEO	0.1116	0.0524	–						
RFEC	0.0111	0.0402	0.0125	–					
LFEO	0.9111	0.8560	0.2525	0.0491	–				
LFEC	0.7167	0.2764	0.9222	0.0120	0.2953	–			
RR	0.9889	0.6056	0.7272	0.0697	0.4766	0.5392	–		
RL	0.0221	0.0655	0.0120	0.4853	0.0836	0.0363	0.0787	–	
RC	0.8890	1.0000	0.6252	0.2764	0.8890	0.8125	0.6857	0.3150	–

Figure G.5 – Boxplot representation and p-values between tasks for COP's mean velocity in X direction.



	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.4853	–							
RFEO	0.4024	0.3218	–						
RFEC	0.8560	0.8233	0.6352	–					
LFEO	0.8233	0.6857	0.9001	0.8017	–				
LFEC	0.8560	0.7802	0.9777	0.6960	0.9777	–			
RR	0.5030	0.6154	0.5392	0.5030	0.5863	0.5209	–		
RL	0.0205	0.0351	0.0198	0.0125	0.0098	0.0275	0.1714	–	
RC	0.5767	0.5119	0.4264	0.4680	0.4853	0.3793	0.8780	0.4511	–

Figure G.6 – Boxplot representation and p-values between tasks for COP's mean velocity in Y direction.

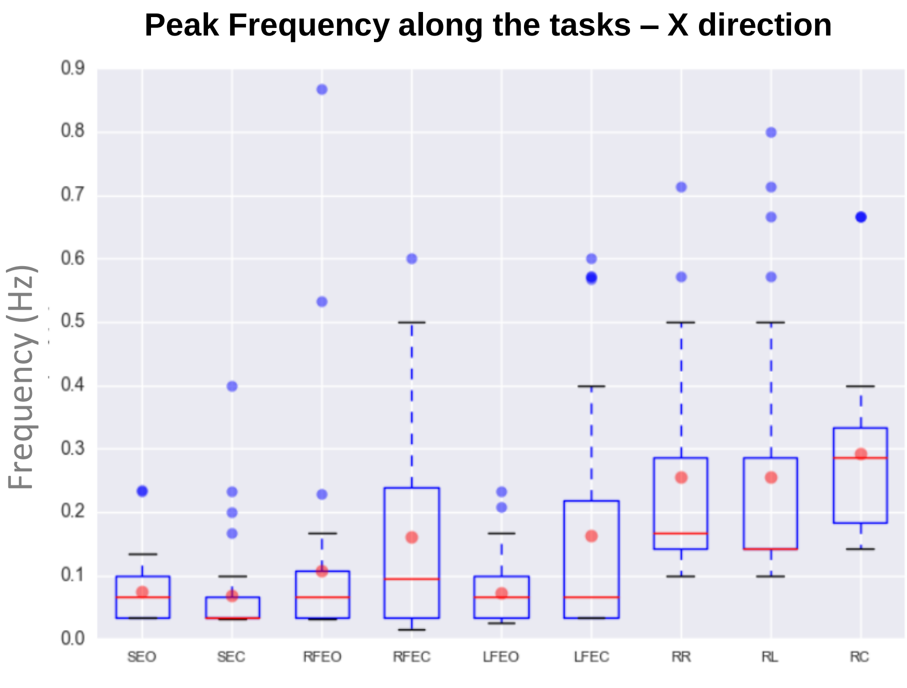


	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.9777	–							
RFEO	0.0001	0.0000	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0001	0.0000	0.1181	0.0000	–				
LFEC	0.0000	0.0000	0.0000	0.3570	0.0000	–			
RR	0.0000	0.0000	0.0001	0.0000	0.0002	0.0000	–		
RL	0.0000	0.0000	0.0000	0.0053	0.0000	0.0019	0.0115	–	
RC	0.0000	0.0000	0.0000	0.0004	0.0000	0.0012	0.2764	0.2247	–

Figure G.7 – Boxplot representation and p-values between tasks for COP's total area displacement.

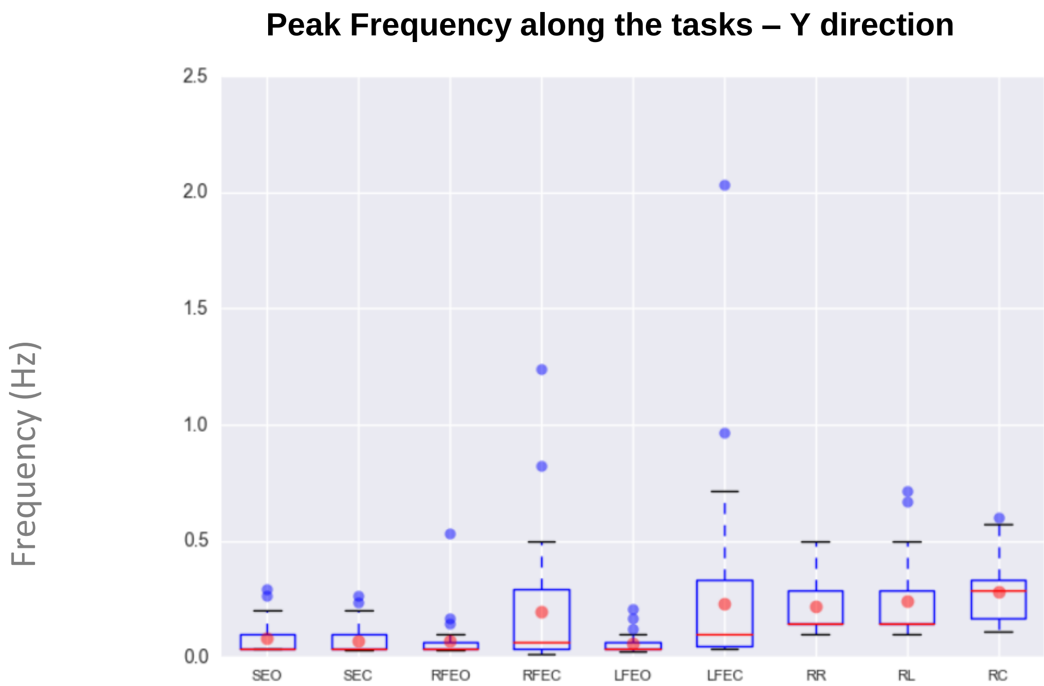
Appendix H

In this chapter the analysis of COP frequencies along all the nine tasks will be presented, for a group of healthy subjects.



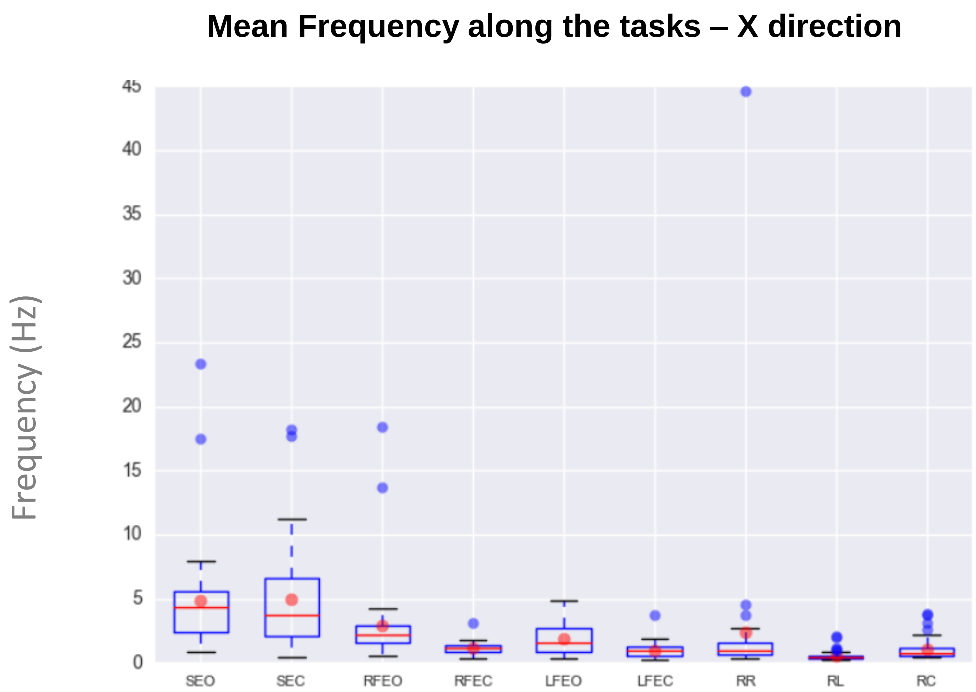
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.3145	–							
RFEO	0.6563	0.1485	–						
RFEC	0.0109	0.0005	0.0493	–					
LFEO	0.7450	0.3795	0.3463	0.0122	–				
LFEC	0.0128	0.0044	0.1173	0.8938	0.0502	–			
RR	0.0000	0.0000	0.0000	0.0017	0.0000	0.0071	–		
RL	0.0000	0.0000	0.0000	0.0029	0.0000	0.0054	1.0000	–	
RC	0.0000	0.0000	0.0000	0.0020	0.0000	0.0011	0.2085	0.0839	–

Figure H.1 – Boxplot representation and p-values between tasks for COP's peak frequency of the displacement in X direction.



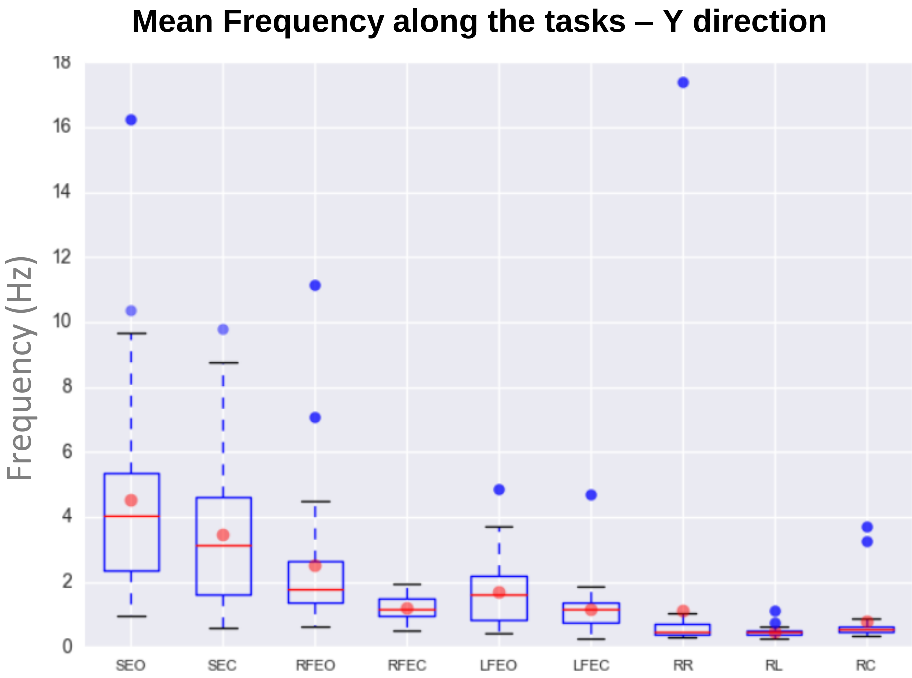
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.3325	–							
RFEO	0.0478	0.5927	–						
RFEC	0.0031	0.0038	0.0023	–					
LFEO	0.1169	0.4378	0.9354	0.0016	–				
LFEC	0.0030	0.0013	0.0006	0.7388	0.0003	–			
RR	0.0000	0.0000	0.0000	0.1504	0.0000	0.2116	–		
RL	0.0000	0.0000	0.0000	0.0184	0.0000	0.0911	0.4704	–	
RC	0.0000	0.0000	0.0000	0.0021	0.0000	0.0026	0.0196	0.0885	–

Figure H.2 – Boxplot representation and p-values between tasks for COP's peak frequency of the displacement in Y direction.



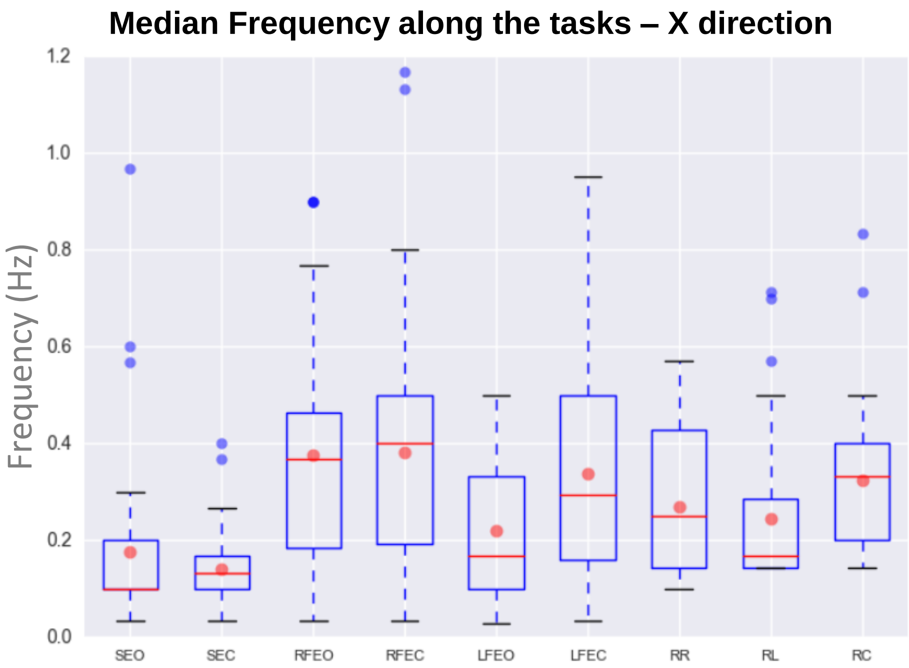
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.7377	–							
RFEO	0.0000	0.0002	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0000	0.0000	0.0787	0.0006	–				
LFEC	0.0000	0.0000	0.0000	0.1248	0.0001	–			
RR	0.0000	0.0000	0.0001	0.6755	0.0094	0.2194	–		
RL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	–	
RC	0.0000	0.0000	0.0000	0.1759	0.0015	0.6154	0.0430	0.0000	–

Figure H.3 – Boxplot representation and p-values between tasks for COP's mean frequency of the displacement in X direction.



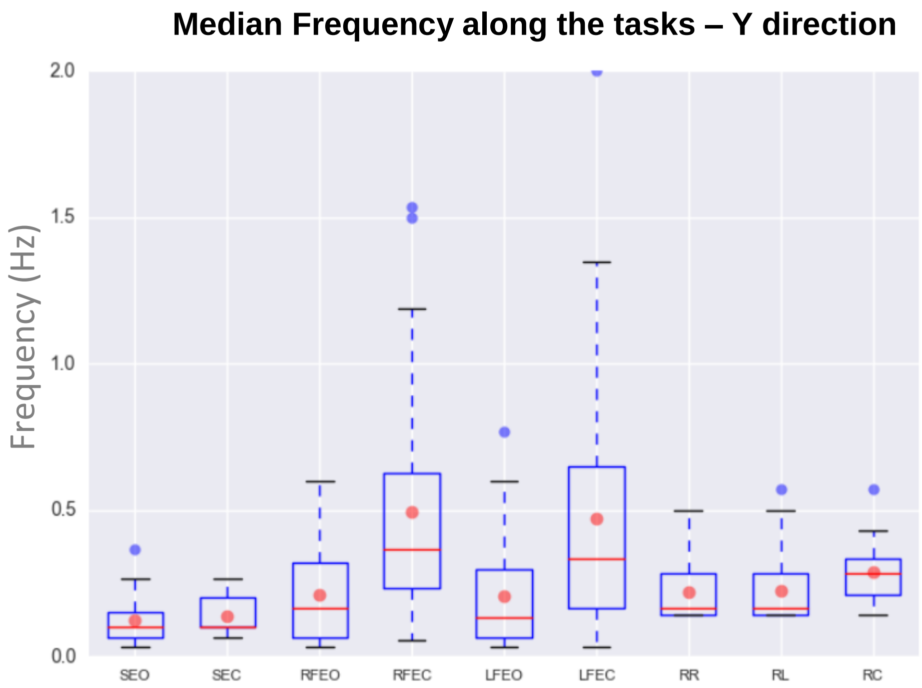
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.1116	–							
RFEO	0.0001	0.0012	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0000	0.0000	0.0697	0.0198	–				
LFEC	0.0000	0.0000	0.0001	0.1428	0.0013	–			
RR	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	–		
RL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.5672	–	
RC	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001	0.0741	0.0026	–

Figure H.4 – Boxplot representation and p-values between tasks for COP's mean frequency of the displacement in Y direction.



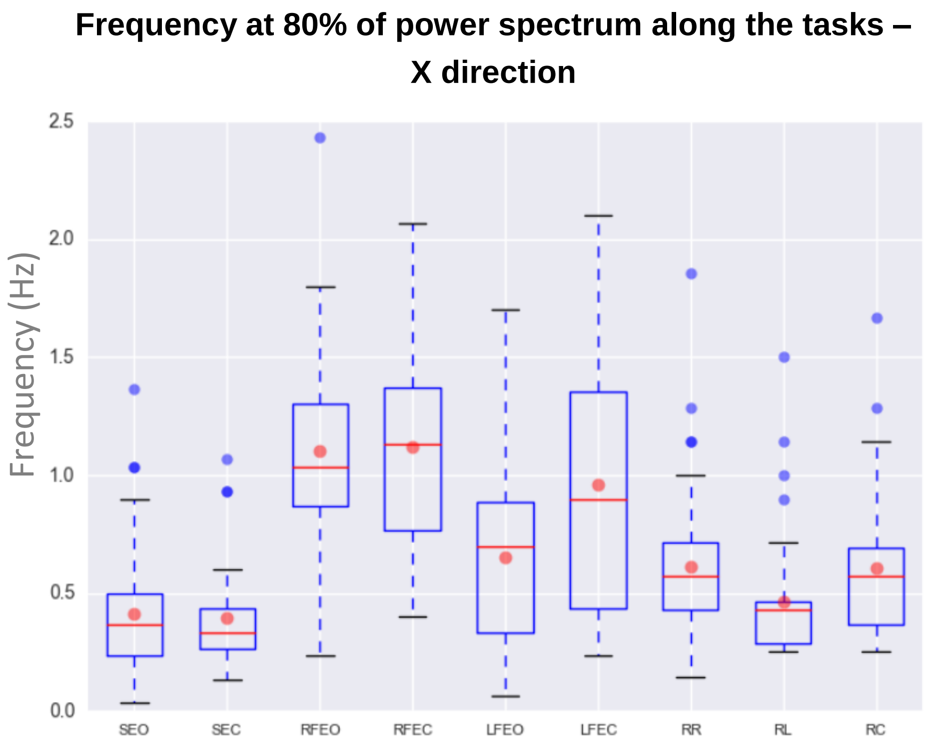
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.3814	–							
RFEO	0.0001	0.0000	–						
RFEC	0.0001	0.0000	0.6782	–					
LFEO	0.1460	0.0066	0.0003	0.0009	–				
LFEC	0.0039	0.0001	0.3421	0.3747	0.0211	–			
RR	0.0006	0.0000	0.0577	0.0305	0.1587	0.2247	–		
RL	0.0048	0.0006	0.0087	0.0035	0.6754	0.0886	0.3734	–	
RC	0.0002	0.0000	0.4386	0.2841	0.0087	0.9937	0.1919	0.0051	–

Figure H.5 – Boxplot representation and p-values between tasks for COP's median frequency of the displacement in X direction.



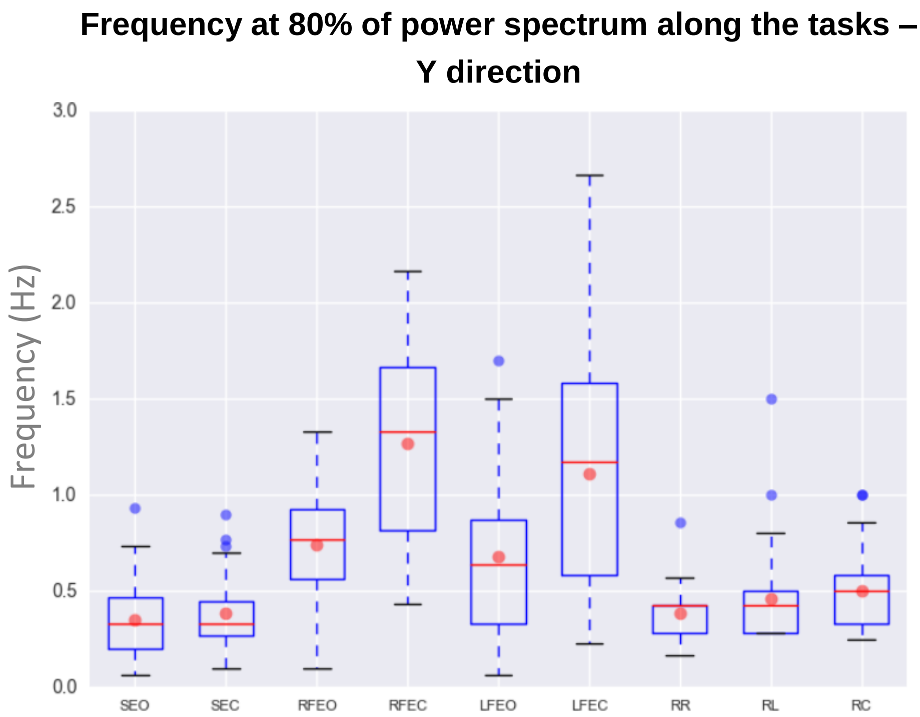
	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.2703	–							
RFEO	0.0025	0.0442	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0493	0.0796	0.7863	0.0001	–				
LFEC	0.0000	0.0000	0.0003	0.6322	0.0002	–			
RR	0.0000	0.0001	0.5670	0.0000	0.2824	0.0010	–		
RL	0.0000	0.0001	0.5718	0.0000	0.2732	0.0018	0.6473	–	
RC	0.0000	0.0000	0.0071	0.0072	0.0131	0.0387	0.0010	0.0017	–

Figure H.6 – Boxplot representation and p-values between tasks for COP's median frequency of the displacement in Y direction.



	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.8622	–							
RFEO	0.0000	0.0000	–						
RFEC	0.0000	0.0000	0.8451	–					
LFEO	0.0008	0.0007	0.0000	0.0001	–				
LFEC	0.0000	0.0000	0.1314	0.0707	0.0026	–			
RR	0.0005	0.0002	0.0000	0.0000	0.3869	0.0008	–		
RL	0.3356	0.3921	0.0000	0.0000	0.0158	0.0001	0.0100	–	
RC	0.0014	0.0007	0.0000	0.0000	0.6451	0.0007	0.7583	0.0036	–

Figure H.7 – Boxplot representation and p-values between tasks for COP's 80% of power spectrum of the displacement in X direction.



	SEO	SEC	RFEO	RFEC	LFEO	LFEC	RR	RL	RC
SEO	–								
SEC	0.4735	–							
RFEO	0.0000	0.0000	–						
RFEC	0.0000	0.0000	0.0000	–					
LFEO	0.0001	0.0002	0.2672	0.0000	–				
LFEC	0.0000	0.0000	0.0019	0.1214	0.0001	–			
RR	0.1692	0.4953	0.0000	0.0000	0.0003	0.0000	–		
RL	0.0205	0.0656	0.0002	0.0000	0.0083	0.0000	0.0826	–	
RC	0.0003	0.0087	0.0003	0.0000	0.0322	0.0000	0.0007	0.0266	–

Figure H.8 – Boxplot representation and p-values between tasks for COP's 80% of power spectrum of the displacement in Y direction.

I

Appendix I

In this chapter it will be found the spearman correlation coefficient (ρ) and the respective p-value between the BMI/Age and every EMG and COP paramenter for a group of healthy subjects.

First will be presented the correlation between the BMI and the EMG and COP parameters, and second the correlation between the same parameters and age.

Next it is presented the description of the tasks performed along the protocol, and the muscles in evaluation.

Tasks:

- SEO = Standing with eyes open;
- SEC = Standing with eyes close;
- RFEO = One leg stand, right leg and eyes open;
- RFEC = One leg stand, right leg and eyes close;
- LFEO = One leg stand, left leg and eyes open;
- LFEC = One leg stand, left leg and eyes close;
- RR = Reaching an object on the right side of the subject with his left hand;
- RL = Reaching an object on the left side of the subject with his right hand;
- RC = Reaching an object in front of the subject dominant hand.

Muscles:

- ReR = Rectus Abdominis Right;
- ReL = Rectus Abdominis Left;
- OR = External Obliques Right;
- OL = External Obliques Left;
- IR = Iliocostalis Right;
- IL = Iliocostalis Left;
- MR = Multifidus Right;
- ML= Multifidus Left.

I.1 – Spearman Correlation between BMI and EMG and COP parameters

Table I.1.1 – Spearman correlation coefficient between BMI values and the mean value of muscle activation, for a group of healthy subjects.

Mean Value of Muscle Activation																		
	SEO		SEC		RFEO		RFEC		LFEO		LFEC		RR		RL		RC	
	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value
ReR	-0,0032	0,9846	0,0475	0,7738	0,1039	0,5290	-0,0734	0,6569	0,1810	0,2700	0,0439	0,7908	-0,2768	0,0880	0,4080	0,0099	0,1704	0,2998
ReL	0,0099	0,9524	-0,0960	0,5610	0,0176	0,9151	-0,0850	0,6071	0,0779	0,6376	-0,2315	0,1561	0,0397	0,8103	0,3176	0,0488	0,1463	0,3742
OR	-0,2987	0,0647	-0,2278	0,1630	-0,4133	0,0089	-0,1939	0,2368	-0,2426	0,1367	-0,2487	0,1268	-0,0413	0,8029	0,3092	0,0555	0,0745	0,6523
OL	-0,2916	0,0717	-0,1070	0,5170	-0,1996	0,2232	-0,1512	0,3582	-0,1312	0,4258	-0,2939	0,0693	0,1329	0,4200	0,2406	0,1400	0,1153	0,4848
IR	-0,0260	0,8752	0,0366	0,8252	0,0431	0,7943	-0,1082	0,5119	-0,0110	0,9472	-0,1747	0,2873	-0,2445	0,1335	0,3148	0,0510	0,3559	0,0262
IL	0,0096	0,9535	-0,0278	0,8665	0,0431	0,7943	0,0673	0,6839	0,0266	0,8721	-0,3676	0,0213	0,2903	0,0730	0,2128	0,1934	0,1988	0,2250
MR	-0,0363	0,8262	-0,0869	0,5990	-0,1638	0,3190	-0,1506	0,3600	-0,1778	0,2788	-0,3451	0,0314	-0,0554	0,7377	0,2715	0,0945	0,2211	0,1762
ML	0,0425	0,7971	0,2805	0,0837	-0,0184	0,9117	-0,1358	0,4097	-0,0751	0,6494	-0,3658	0,0220	0,2765	0,0884	0,3683	0,0210	0,3118	0,0533

Table I.1.2 – Spearman correlation coefficient between BMI values and Peak frequency of EMG signal, for a group of healthy subjects.

Peak Frequency of EMG																		
	SEO		SEC		RFEO		RFEC		LFEO		LFEC		RR		RL		RC	
	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value
ReR	-0,0032	0,9846	0,0475	0,7738	0,1039	0,5290	-0,0734	0,6569	0,1810	0,2700	0,0439	0,7908	-0,2768	0,0880	0,4080	0,0099	0,1704	0,2998
ReL	0,0099	0,9524	-0,0960	0,5610	0,0176	0,9151	-0,0850	0,6071	0,0779	0,6376	-0,2315	0,1561	0,0397	0,8103	0,3176	0,0488	0,1463	0,3742
OR	-0,2987	0,0647	-0,2278	0,1630	-0,4133	0,0089	-0,1939	0,2368	-0,2426	0,1367	-0,2487	0,1268	-0,0413	0,8029	0,3092	0,0555	0,0745	0,6523
OL	-0,2916	0,0717	-0,1070	0,5170	-0,1996	0,2232	-0,1512	0,3582	-0,1312	0,4258	-0,2939	0,0693	0,1329	0,4200	0,2406	0,1400	0,1153	0,4848
IR	-0,0260	0,8752	0,0366	0,8252	0,0431	0,7943	-0,1082	0,5119	-0,0110	0,9472	-0,1747	0,2873	-0,2445	0,1335	0,3148	0,0510	0,3559	0,0262
IL	0,0096	0,9535	-0,0278	0,8665	0,0431	0,7943	0,0673	0,6839	0,0266	0,8721	-0,3676	0,0213	0,2903	0,0730	0,2128	0,1934	0,1988	0,2250
MR	-0,0363	0,8262	-0,0869	0,5990	-0,1638	0,3190	-0,1506	0,3600	-0,1778	0,2788	-0,3451	0,0314	-0,0554	0,7377	0,2715	0,0945	0,2211	0,1762
ML	0,0425	0,7971	0,2805	0,0837	-0,0184	0,9117	-0,1358	0,4097	-0,0751	0,6494	-0,3658	0,0220	0,2765	0,0884	0,3683	0,0210	0,3118	0,0533

Table I.1.3 – Spearman correlation coefficient between BMI values and Mean frequency of EMG signal, for a group of healthy subjects.

Mean Frequency of EMG	SEO		SEC		RFEO		RFEC		LFEO		LFEC		RR		RL		RC	
	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value
ReR	-0,0032	0,9846	0,0475	0,7738	0,1039	0,5290	-0,0734	0,6569	0,1810	0,2700	0,0439	0,7908	-0,2768	0,0880	0,4080	0,0099	0,1704	0,2998
ReL	0,0099	0,9524	-0,0960	0,5610	0,0176	0,9151	-0,0850	0,6071	0,0779	0,6376	-0,2315	0,1561	0,0397	0,8103	0,3176	0,0488	0,1463	0,3742
OR	-0,2987	0,0647	-0,2278	0,1630	-0,4133	0,0089	-0,1939	0,2368	-0,2426	0,1367	-0,2487	0,1268	-0,0413	0,8029	0,3092	0,0555	0,0745	0,6523
OL	-0,2916	0,0717	-0,1070	0,5170	-0,1996	0,2232	-0,1512	0,3582	-0,1312	0,4258	-0,2939	0,0693	0,1329	0,4200	0,2406	0,1400	0,1153	0,4848
IR	-0,0260	0,8752	0,0366	0,8252	0,0431	0,7943	-0,1082	0,5119	-0,0110	0,9472	-0,1747	0,2873	-0,2445	0,1335	0,3148	0,0510	0,3559	0,0262
IL	0,0096	0,9535	-0,0278	0,8665	0,0431	0,7943	0,0673	0,6839	0,0266	0,8721	-0,3676	0,0213	0,2903	0,0730	0,2128	0,1934	0,1988	0,2250
MR	-0,0363	0,8262	-0,0869	0,5990	-0,1638	0,3190	-0,1506	0,3600	-0,1778	0,2788	-0,3451	0,0314	-0,0554	0,7377	0,2715	0,0945	0,2211	0,1762
ML	0,0425	0,7971	0,2805	0,0837	-0,0184	0,9117	-0,1358	0,4097	-0,0751	0,6494	-0,3658	0,0220	0,2765	0,0884	0,3683	0,0210	0,3118	0,0533

Table I.1.4 – Spearman correlation coefficient between BMI values and Median frequency of EMG signal, for a group of healthy subjects.

Median Frequency of EMG																		
	SEO		SEC		RFEO		RFEC		LFEO		LFEC		RR		RL		RC	
	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value
ReR	-0,0032	0,9846	0,0475	0,7738	0,1039	0,5290	-0,0734	0,6569	0,1810	0,2700	0,0439	0,7908	-0,2768	0,0880	0,4080	0,0099	0,1704	0,2998
ReL	0,0099	0,9524	-0,0960	0,5610	0,0176	0,9151	-0,0850	0,6071	0,0779	0,6376	-0,2315	0,1561	0,0397	0,8103	0,3176	0,0488	0,1463	0,3742
OR	-0,2987	0,0647	-0,2278	0,1630	-0,4133	0,0089	-0,1939	0,2368	-0,2426	0,1367	-0,2487	0,1268	-0,0413	0,8029	0,3092	0,0555	0,0745	0,6523
OL	-0,2916	0,0717	-0,1070	0,5170	-0,1996	0,2232	-0,1512	0,3582	-0,1312	0,4258	-0,2939	0,0693	0,1329	0,4200	0,2406	0,1400	0,1153	0,4848
IR	-0,0260	0,8752	0,0366	0,8252	0,0431	0,7943	-0,1082	0,5119	-0,0110	0,9472	-0,1747	0,2873	-0,2445	0,1335	0,3148	0,0510	0,3559	0,0262
IL	0,0096	0,9535	-0,0278	0,8665	0,0431	0,7943	0,0673	0,6839	0,0266	0,8721	-0,3676	0,0213	0,2903	0,0730	0,2128	0,1934	0,1988	0,2250
MR	-0,0363	0,8262	-0,0869	0,5990	-0,1638	0,3190	-0,1506	0,3600	-0,1778	0,2788	-0,3451	0,0314	-0,0554	0,7377	0,2715	0,0945	0,2211	0,1762
ML	0,0425	0,7971	0,2805	0,0837	-0,0184	0,9117	-0,1358	0,4097	-0,0751	0,6494	-0,3658	0,0220	0,2765	0,0884	0,3683	0,0210	0,3118	0,0533

Table I.1.5 – Spearman correlation coefficient between BMI values and frequency at 80% of power spectrum of EMG signal, for a group of healthy subjects.

Frequency at 80% of power spectrum of EMG		ReR	ReL	OR	OL	IR	IL	MR	ML
SEO	(ρ)	-0,0032	0,0099	-0,2987	-0,2916	-0,0260	0,0096	-0,0363	0,0425
	p-value	0,9846	0,9524	0,0647	0,0717	0,8752	0,9535	0,8262	0,7971
SEC	(ρ)	0,0475	-0,0960	-0,2278	-0,1070	0,0366	-0,0278	-0,0869	0,2805
	p-value	0,7738	0,5610	0,1630	0,5170	0,8252	0,8665	0,5990	0,0837
RFEO	(ρ)	0,1039	0,0176	-0,4133	-0,1996	0,0431	0,0431	-0,1638	-0,0184
	p-value	0,5290	0,9151	0,0089	0,2232	0,7943	0,7943	0,3190	0,9117
RFEC	(ρ)	-0,0734	-0,0850	-0,1939	-0,1512	-0,1082	0,0673	-0,1506	-0,1358
	p-value	0,6569	0,6071	0,2368	0,3582	0,5119	0,6839	0,3600	0,4097
LFEO	(ρ)	0,1810	0,0779	-0,2426	-0,1312	-0,0110	0,0266	-0,1778	-0,0751
	p-value	0,2700	0,6376	0,1367	0,4258	0,9472	0,8721	0,2788	0,6494
LFEC	(ρ)	0,0439	-0,2315	-0,2487	-0,2939	-0,1747	-0,3676	-0,3451	-0,3658
	p-value	0,7908	0,1561	0,1268	0,0693	0,2873	0,0213	0,0314	0,0220
RR	(ρ)	-0,2768	0,0397	-0,0413	0,1329	-0,2445	0,2903	-0,0554	0,2765
	p-value	0,0880	0,8103	0,8029	0,4200	0,1335	0,0730	0,7377	0,0884
RL	(ρ)	0,4080	0,3176	0,3092	0,2406	0,3148	0,2128	0,2715	0,3683
	p-value	0,0099	0,0488	0,0555	0,1400	0,0510	0,1934	0,0945	0,0210
RC	(ρ)	0,1704	0,1463	0,0745	0,1153	0,3559	0,1988	0,2211	0,3118
	p-value	0,2998	0,3742	0,6523	0,4848	0,0262	0,2250	0,1762	0,0533

Table I.1.6 – Spearman correlation coefficient between BMI values and COP parameters, for a group of healthy subjects.

		COP Parameters						
		Amplitude X	Amplitude Y	STD X	STD Y	Velocity X	Velocity Y	Area
SEO	(ρ)	-0,0032	0,0099	-0,2987	-0,2916	-0,0260	0,0096	-0,0363
	p-value	0,9846	0,9524	0,0647	0,0717	0,8752	0,9535	0,8262
SEC	(ρ)	0,0475	-0,0960	-0,2278	-0,1070	0,0366	-0,0278	-0,0869
	p-value	0,7738	0,5610	0,1630	0,5170	0,8252	0,8665	0,5990
RFEO	(ρ)	0,1039	0,0176	-0,4133	-0,1996	0,0431	0,0431	-0,1638
	p-value	0,5290	0,9151	0,0089	0,2232	0,7943	0,7943	0,3190
RFEC	(ρ)	-0,0734	-0,0850	-0,1939	-0,1512	-0,1082	0,0673	-0,1506
	p-value	0,6569	0,6071	0,2368	0,3582	0,5119	0,6839	0,3600
LFEO	(ρ)	0,1810	0,0779	-0,2426	-0,1312	-0,0110	0,0266	-0,1778
	p-value	0,2700	0,6376	0,1367	0,4258	0,9472	0,8721	0,2788
LFEC	(ρ)	0,0439	-0,2315	-0,2487	-0,2939	-0,1747	-0,3676	-0,3451
	p-value	0,7908	0,1561	0,1268	0,0693	0,2873	0,0213	0,0314
RR	(ρ)	-0,2768	0,0397	-0,0413	0,1329	-0,2445	0,2903	-0,0554
	p-value	0,0880	0,8103	0,8029	0,4200	0,1335	0,0730	0,7377
RL	(ρ)	0,4080	0,3176	0,3092	0,2406	0,3148	0,2128	0,2715
	p-value	0,0099	0,0488	0,0555	0,1400	0,0510	0,1934	0,0945
RC	(ρ)	0,1704	0,1463	0,0745	0,1153	0,3559	0,1988	0,2211
	p-value	0,2998	0,3742	0,6523	0,4848	0,0262	0,2250	0,1762

Table I.1.7 – Spearman correlation coefficient between BMI values and COP frequencies, for a group of healthy subjects. Peak frequency in both directions (Peak X and Peak Y), mean frequency in both directions (Mean X and Mean Y), median frequency in both directions (Median X and Median Y), and Frequency at 80% of power spectrum in both directions (80% X and 80% Y)

Frequency at 80% of power spectrum of EMG																		
	SEO		SEC		RFEO		RFEC		LFEO		LFEC		RR		RL		RC	
	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value
Peak X	-0,0032	0,9846	0,0475	0,7738	0,1039	0,5290	-0,0734	0,6569	0,1810	0,2700	0,0439	0,7908	-0,2768	0,0880	0,4080	0,0099	0,1704	0,2998
Peak Y	0,0099	0,9524	-0,0960	0,5610	0,0176	0,9151	-0,0850	0,6071	0,0779	0,6376	-0,2315	0,1561	0,0397	0,8103	0,3176	0,0488	0,1463	0,3742
Mean X	-0,2987	0,0647	-0,2278	0,1630	-0,4133	0,0089	-0,1939	0,2368	-0,2426	0,1367	-0,2487	0,1268	-0,0413	0,8029	0,3092	0,0555	0,0745	0,6523
Mean Y	-0,2916	0,0717	-0,1070	0,5170	-0,1996	0,2232	-0,1512	0,3582	-0,1312	0,4258	-0,2939	0,0693	0,1329	0,4200	0,2406	0,1400	0,1153	0,4848
Median X	-0,0260	0,8752	0,0366	0,8252	0,0431	0,7943	-0,1082	0,5119	-0,0110	0,9472	-0,1747	0,2873	-0,2445	0,1335	0,3148	0,0510	0,3559	0,0262
Median Y	0,0096	0,9535	-0,0278	0,8665	0,0431	0,7943	0,0673	0,6839	0,0266	0,8721	-0,3676	0,0213	0,2903	0,0730	0,2128	0,1934	0,1988	0,2250
80% X	-0,0363	0,8262	-0,0869	0,5990	-0,1638	0,3190	-0,1506	0,3600	-0,1778	0,2788	-0,3451	0,0314	-0,0554	0,7377	0,2715	0,0945	0,2211	0,1762
80% Y	0,0425	0,7971	0,2805	0,0837	-0,0184	0,9117	-0,1358	0,4097	-0,0751	0,6494	-0,3658	0,0220	0,2765	0,0884	0,3683	0,0210	0,3118	0,0533

I.2 – Spearman Correlation between age and EMG and COP parameters

Table I.2.1 – Spearman correlation coefficient between age values and the mean value of muscle activation, for a group of healthy subjects.

Mean Value of Muscle Activation																		
	SEO		SEC		RFEO		RFEC		LFEO		LFEC		RR		RL		RC	
	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value
ReR	-0,0032	0,9846	0,0475	0,7738	0,1039	0,5290	-0,0734	0,6569	0,1810	0,2700	0,0439	0,7908	-0,2768	0,0880	0,4080	0,0099	0,1704	0,2998
ReL	0,0099	0,9524	-0,0960	0,5610	0,0176	0,9151	-0,0850	0,6071	0,0779	0,6376	-0,2315	0,1561	0,0397	0,8103	0,3176	0,0488	0,1463	0,3742
OR	-0,2987	0,0647	-0,2278	0,1630	-0,4133	0,0089	-0,1939	0,2368	-0,2426	0,1367	-0,2487	0,1268	-0,0413	0,8029	0,3092	0,0555	0,0745	0,6523
OL	-0,2916	0,0717	-0,1070	0,5170	-0,1996	0,2232	-0,1512	0,3582	-0,1312	0,4258	-0,2939	0,0693	0,1329	0,4200	0,2406	0,1400	0,1153	0,4848
IR	-0,0260	0,8752	0,0366	0,8252	0,0431	0,7943	-0,1082	0,5119	-0,0110	0,9472	-0,1747	0,2873	-0,2445	0,1335	0,3148	0,0510	0,3559	0,0262
IL	0,0096	0,9535	-0,0278	0,8665	0,0431	0,7943	0,0673	0,6839	0,0266	0,8721	-0,3676	0,0213	0,2903	0,0730	0,2128	0,1934	0,1988	0,2250
MR	-0,0363	0,8262	-0,0869	0,5990	-0,1638	0,3190	-0,1506	0,3600	-0,1778	0,2788	-0,3451	0,0314	-0,0554	0,7377	0,2715	0,0945	0,2211	0,1762
ML	0,0425	0,7971	0,2805	0,0837	-0,0184	0,9117	-0,1358	0,4097	-0,0751	0,6494	-0,3658	0,0220	0,2765	0,0884	0,3683	0,0210	0,3118	0,0533

Table I.2.2 – Spearman correlation coefficient between BMI values and Peak frequency of EMG signal, for a group of healthy subjects.

Peak Frequency of EMG																		
	SEO		SEC		RFEO		RFEC		LFEO		LFEC		RR		RL		RC	
	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value
ReR	-0,0032	0,9846	0,0475	0,7738	0,1039	0,5290	-0,0734	0,6569	0,1810	0,2700	0,0439	0,7908	-0,2768	0,0880	0,4080	0,0099	0,1704	0,2998
ReL	0,0099	0,9524	-0,0960	0,5610	0,0176	0,9151	-0,0850	0,6071	0,0779	0,6376	-0,2315	0,1561	0,0397	0,8103	0,3176	0,0488	0,1463	0,3742
OR	-0,2987	0,0647	-0,2278	0,1630	-0,4133	0,0089	-0,1939	0,2368	-0,2426	0,1367	-0,2487	0,1268	-0,0413	0,8029	0,3092	0,0555	0,0745	0,6523
OL	-0,2916	0,0717	-0,1070	0,5170	-0,1996	0,2232	-0,1512	0,3582	-0,1312	0,4258	-0,2939	0,0693	0,1329	0,4200	0,2406	0,1400	0,1153	0,4848
IR	-0,0260	0,8752	0,0366	0,8252	0,0431	0,7943	-0,1082	0,5119	-0,0110	0,9472	-0,1747	0,2873	-0,2445	0,1335	0,3148	0,0510	0,3559	0,0262
IL	0,0096	0,9535	-0,0278	0,8665	0,0431	0,7943	0,0673	0,6839	0,0266	0,8721	-0,3676	0,0213	0,2903	0,0730	0,2128	0,1934	0,1988	0,2250
MR	-0,0363	0,8262	-0,0869	0,5990	-0,1638	0,3190	-0,1506	0,3600	-0,1778	0,2788	-0,3451	0,0314	-0,0554	0,7377	0,2715	0,0945	0,2211	0,1762
ML	0,0425	0,7971	0,2805	0,0837	-0,0184	0,9117	-0,1358	0,4097	-0,0751	0,6494	-0,3658	0,0220	0,2765	0,0884	0,3683	0,0210	0,3118	0,0533

Table I.2.3 – Spearman correlation coefficient between BMI values and Mean frequency of EMG signal, for a group of healthy subjects.

Mean Frequency of EMG																		
	SEO		SEC		RFEO		RFEC		LFEO		LFEC		RR		RL		RC	
	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value
ReR	-0,0032	0,9846	0,0475	0,7738	0,1039	0,5290	-0,0734	0,6569	0,1810	0,2700	0,0439	0,7908	-0,2768	0,0880	0,4080	0,0099	0,1704	0,2998
ReL	0,0099	0,9524	-0,0960	0,5610	0,0176	0,9151	-0,0850	0,6071	0,0779	0,6376	-0,2315	0,1561	0,0397	0,8103	0,3176	0,0488	0,1463	0,3742
OR	-0,2987	0,0647	-0,2278	0,1630	-0,4133	0,0089	-0,1939	0,2368	-0,2426	0,1367	-0,2487	0,1268	-0,0413	0,8029	0,3092	0,0555	0,0745	0,6523
OL	-0,2916	0,0717	-0,1070	0,5170	-0,1996	0,2232	-0,1512	0,3582	-0,1312	0,4258	-0,2939	0,0693	0,1329	0,4200	0,2406	0,1400	0,1153	0,4848
IR	-0,0260	0,8752	0,0366	0,8252	0,0431	0,7943	-0,1082	0,5119	-0,0110	0,9472	-0,1747	0,2873	-0,2445	0,1335	0,3148	0,0510	0,3559	0,0262
IL	0,0096	0,9535	-0,0278	0,8665	0,0431	0,7943	0,0673	0,6839	0,0266	0,8721	-0,3676	0,0213	0,2903	0,0730	0,2128	0,1934	0,1988	0,2250
MR	-0,0363	0,8262	-0,0869	0,5990	-0,1638	0,3190	-0,1506	0,3600	-0,1778	0,2788	-0,3451	0,0314	-0,0554	0,7377	0,2715	0,0945	0,2211	0,1762
ML	0,0425	0,7971	0,2805	0,0837	-0,0184	0,9117	-0,1358	0,4097	-0,0751	0,6494	-0,3658	0,0220	0,2765	0,0884	0,3683	0,0210	0,3118	0,0533

Table I.2.4 – Spearman correlation coefficient between BMI values and Median frequency of EMG signal, for a group of healthy subjects.

Median Frequency of EMG																		
	SEO		**SEC**		**RFEO**		**RFEC**		**LFEO**		**LFEC**		**RR**		**RL**		**RC**	
	(ρ)	**p-value**	**(ρ)**	**p-value**	**(ρ)**	**p-value**	**(ρ)**	**p-value**	**(ρ)**	**p-value**	**(ρ)**	**p-value**	**(ρ)**	**p-value**	**(ρ)**	**p-value**	**(ρ)**	**p-value**
ReR	0,0182	0,9122	0,0438	0,7911	0,0651	0,6938	0,0934	0,5717	0,0146	0,9299	-0,0042	0,9797	-0,0557	0,7362	-0,0111	0,9467	0,0954	0,5634
ReL	-0,1800	0,2729	-0,2352	0,1494	-0,1725	0,2937	-0,2663	0,1013	-0,2317	0,1559	-0,2389	0,1429	0,0415	0,8020	-0,0861	0,6023	-0,1200	0,4667
OR	0,3011	0,0625	0,369	0,0208	0,2495	0,1255	0,0879	0,5948	0,1324	0,4216	0,2304	0,1582	0,413	0,009	0,183	0,2648	0,3468	0,0306
OL	0,3421	0,0330	0,3037	0,0602	0,3574	0,0255	0,2235	0,1714	0,2303	0,1584	0,1262	0,4439	0,3571	0,0256	0,26	0,1099	0,0857	0,604
IR	0,2474	0,1289	0,3141	0,0515	0,184	0,2621	0,1855	0,2583	0,1618	0,3250	0,1851	0,2592	-0,0367	0,8245	-0,1873	0,2535	-0,0394	0,812
IL	-0,1288	0,4346	-0,0702	0,6711	0,0544	0,7424	0,2882	0,0752	-0,2024	0,2166	-0,1521	0,3554	-0,0565	0,7328	-0,0013	0,9936	-0,1765	0,2824
MR	0,1905	0,2453	0,2880	0,0754	0,2254	0,1677	0,2922	0,0711	0,1937	0,2374	0,2853	0,0784	0,0057	0,9726	0,1510	0,3587	0,1220	0,4594
ML	0,3859	0,0153	0,3643	0,0226	0,3948	0,0129	0,3616	0,0237	0,3492	0,0293	0,2688	0,0981	-0,2610	0,1085	0,0235	0,8869	0,0524	0,7515

Table I.2.5 – Spearman correlation coefficient between BMI values and frequency at 80% of power spectrum of EMG signal, for a group of healthy subjects.

Frequency at 80% of power spectrum of EMG	SEO		SEC		RFEO		RFEC		LFEO		LFEC		RR		RL		RC	
	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value
ReR	0,2444	0,1337	0,2075	0,2049	0,3849	0,0155	0,3635	0,0229	0,4272	0,0067	0,3992	0,0118	0,0042	0,9798	-0,1511	0,3584	0,0875	0,5963
ReL	0,1367	0,4067	0,1952	0,2337	0,2279	0,1629	0,0168	0,9191	0,0891	0,5895	0,1644	0,3172	0,0700	0,6718	0,0114	0,9452	0,0181	0,9130
OR	0,2362	0,1477	0,2585	0,1121	0,1104	0,5034	0,1336	0,4174	0,1737	0,2902	0,2684	0,0985	0,4087	0,0098	0,0552	0,7384	0,2166	0,1854
OL	0,3203	0,0468	0,295	0,0683	0,3567	0,0258	0,4447	0,0046	0,2975	0,0658	0,2280	0,1627	0,1592	0,3329	0,2581	0,1127	0,0698	0,673
IR	0,0628	0,7043	0,0992	0,5481	-0,0557	0,7363	0,1911	0,2438	-0,0574	0,7286	0,0182	0,9123	-0,086	0,6028	-0,1791	0,2753	0,0125	0,9398
IL	-0,2379	0,1448	-0,2931	0,0702	-0,122	0,4593	0,159	0,3337	-0,3395	0,0345	-0,1329	0,42	-0,0927	0,5747	-0,152	0,3558	-0,1615	0,3259
MR	0,0824	0,6181	0,2206	0,1773	0,2598	0,1103	0,4111	0,0093	-0,0434	0,7929	0,3094	0,0553	-0,0621	0,7072	0,1021	0,5364	0,1636	0,3196
ML	0,1225	0,4574	0,0935	0,5713	0,3043	0,0596	0,2839	0,0798	-0,0337	0,8386	0,1015	0,5387	0,0919	0,5778	0,089	0,5900	0,0580	0,7260

Table I.2.6 – Spearman correlation coefficient between BMI values and COP parameters, for a group of healthy subjects.

	COP Parameters																	
	SEO		SEC		RFEO		RFEC		LFEO		LFEC		RR		RL		RC	
	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value	(ρ)	p-value
Amplitude X	-0,0969	0,5573	0,0373	0,8217	0,1996	0,2232	-0,2060	0,2083	0,1833	0,2641	-0,0041	0,9802	-0,0449	0,7862	-0,0486	0,7691	-0,0659	0,6903
Amplitude Y	0,0196	0,9059	-0,0422	0,7986	0,1367	0,4068	-0,1543	0,3484	0,1081	0,5125	-0,1623	0,3236	0,0295	0,8585	0,0169	0,9186	-0,0288	0,8619
STD X	0,0841	0,6107	0,0505	0,7601	0,2519	0,1218	-0,1607	0,3283	0,2084	0,2030	0,0337	0,8386	-0,0401	0,8087	-0,0337	0,8386	-0,1881	0,2515
STD Y	0,1073	0,5157	-0,0745	0,6523	0,0473	0,7748	-0,1286	0,4354	0,0784	0,6353	-0,0127	0,9388	-0,1045	0,5267	0,0001	0,9995	-0,2154	0,1878
Velocity X	-0,1861	0,2565	0,1817	0,2682	-0,1498	0,3628	0,0623	0,7064	-0,5529	0,0003	-0,1562	0,3422	-0,1917	0,2424	-0,2217	0,1750	0,0704	0,6703
Velocity Y	0,1042	0,5279	-0,2070	0,2060	0,0584	0,7240	0,2624	0,1066	0,4529	0,0038	0,1418	0,3892	0,3555	0,0264	0,2651	0,1028	-0,0196	0,9059
Area	-0,1017	0,5377	0,1352	0,4118	0,0951	0,5648	-0,1807	0,2709	0,2465	0,1304	-0,1187	0,4716	0,0327	0,8434	-0,0185	0,9108	-0,0138	0,9334

Table I.2.7 – Spearman correlation coefficient between BMI values and COP frequencies, for a group of healthy subjects. Peak frequency in both directions (Peak X and Peak Y), mean frequency in both directions (Mean X and Mean Y), median frequency in both directions (Median X and Median Y), and Frequency at 80% of power spectrum in both directions (80% X and 80% Y)

COP Frequencies		Peak X	Peak Y	Mean X	Mean Y	Median X	Median Y	80% X	80% Y
SEO	(ρ)	-0,0032	0,0099	-0,2987	-0,2916	-0,0260	0,0096	-0,0363	0,0425
	p-value	0,9846	0,9524	0,0647	0,0717	0,8752	0,9535	0,8262	0,7971
SEC	(ρ)	0,0475	-0,0960	-0,2278	-0,1070	0,0366	-0,0278	-0,0869	0,2805
	p-value	0,7738	0,5610	0,1630	0,5170	0,8252	0,8665	0,5990	0,0837
RFEO	(ρ)	0,1039	0,0176	-0,4133	-0,1996	0,0431	0,0431	-0,1638	-0,0184
	p-value	0,5290	0,9151	0,0089	0,2232	0,7943	0,7943	0,3190	0,9117
RFEC	(ρ)	-0,0734	-0,0850	-0,1939	-0,1512	-0,1082	0,0673	-0,1506	-0,1358
	p-value	0,6569	0,6071	0,2368	0,3582	0,5119	0,6839	0,3600	0,4097
LFEO	(ρ)	0,1810	0,0779	-0,2426	-0,1312	-0,0110	0,0266	-0,1778	-0,0751
	p-value	0,2700	0,6376	0,1367	0,4258	0,9472	0,8721	0,2788	0,6494
LFEC	(ρ)	0,0439	-0,2315	-0,2487	-0,2939	-0,1747	-0,3676	-0,3451	-0,3658
	p-value	0,7908	0,1561	0,1268	0,0693	0,2873	0,0213	0,0314	0,0220
RR	(ρ)	-0,2768	0,0397	-0,0413	0,1329	-0,2445	0,2903	-0,0554	0,2765
	p-value	0,0880	0,8103	0,8029	0,4200	0,1335	0,0730	0,7377	0,0884
RL	(ρ)	0,4080	0,3176	0,3092	0,2406	0,3148	0,2128	0,2715	0,3683
	p-value	0,0099	0,0488	0,0555	0,1400	0,0510	0,1934	0,0945	0,0210
RC	(ρ)	0,1704	0,1463	0,0745	0,1153	0,3559	0,1988	0,2211	0,3118
	p-value	0,2998	0,3742	0,6523	0,4848	0,0262	0,2250	0,1762	0,0533

J

Appendix J

In this chapter the results regarding the analysis between the two groups that participated on the study, will be presented. First the analysis regarding muscle activation and muscle frequency along all the nine tasks, and then the analysis regarding COP parameters, such as amplitude, standard deviation of COP signals, mean velocity, area and COP frequencies.

J.1 - Muscle Activation

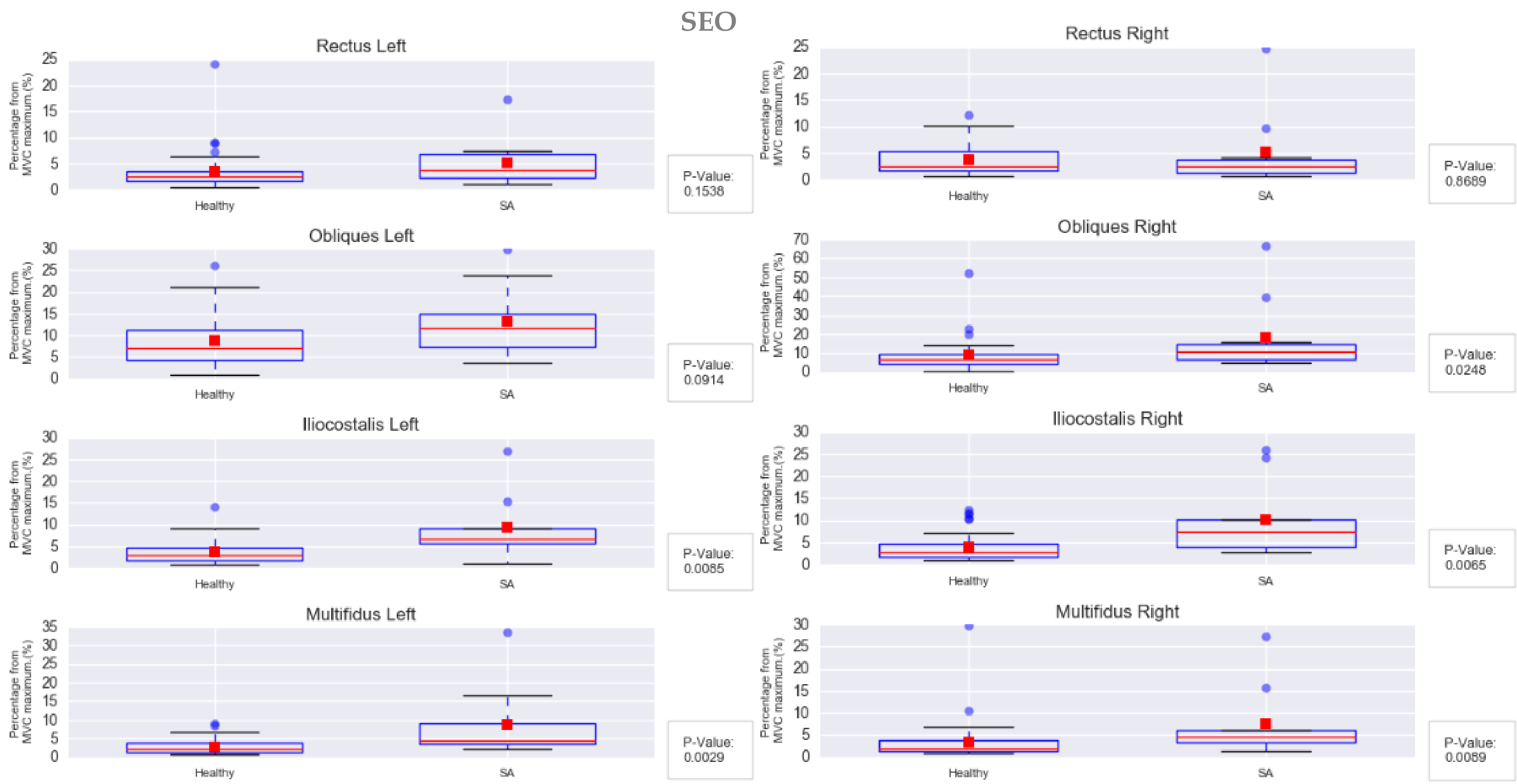


Figure J.1.1 – Boxplot representation of each muscle mean activation for a group of healthy subjects and a group of subjects with ankylosant spondylitis. P-value regarding Mann-Whitney test between the two groups, is represented beside each graphical representation. Graphical representation for SEO (Standing Eyes Open) task.

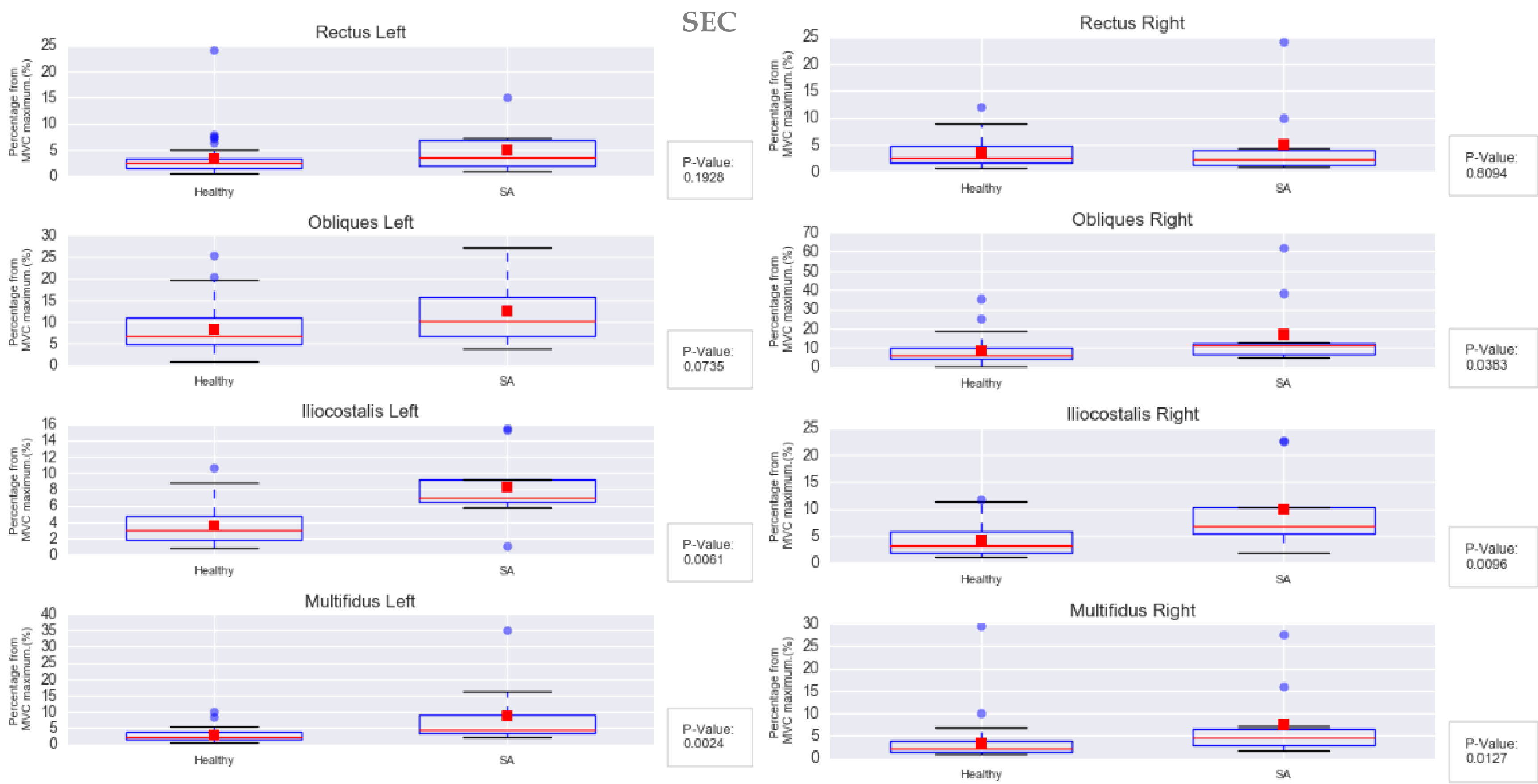


Figure J.1.2 – Boxplot representation of each muscle mean activation for a group of healthy subjects and a group of subjects with ankylosant spondylitis. P-value regarding Mann-Whitney test between the two groups, is represented beside each graphical representation. Graphical representation for SEC (Standing Eyes Close) task.

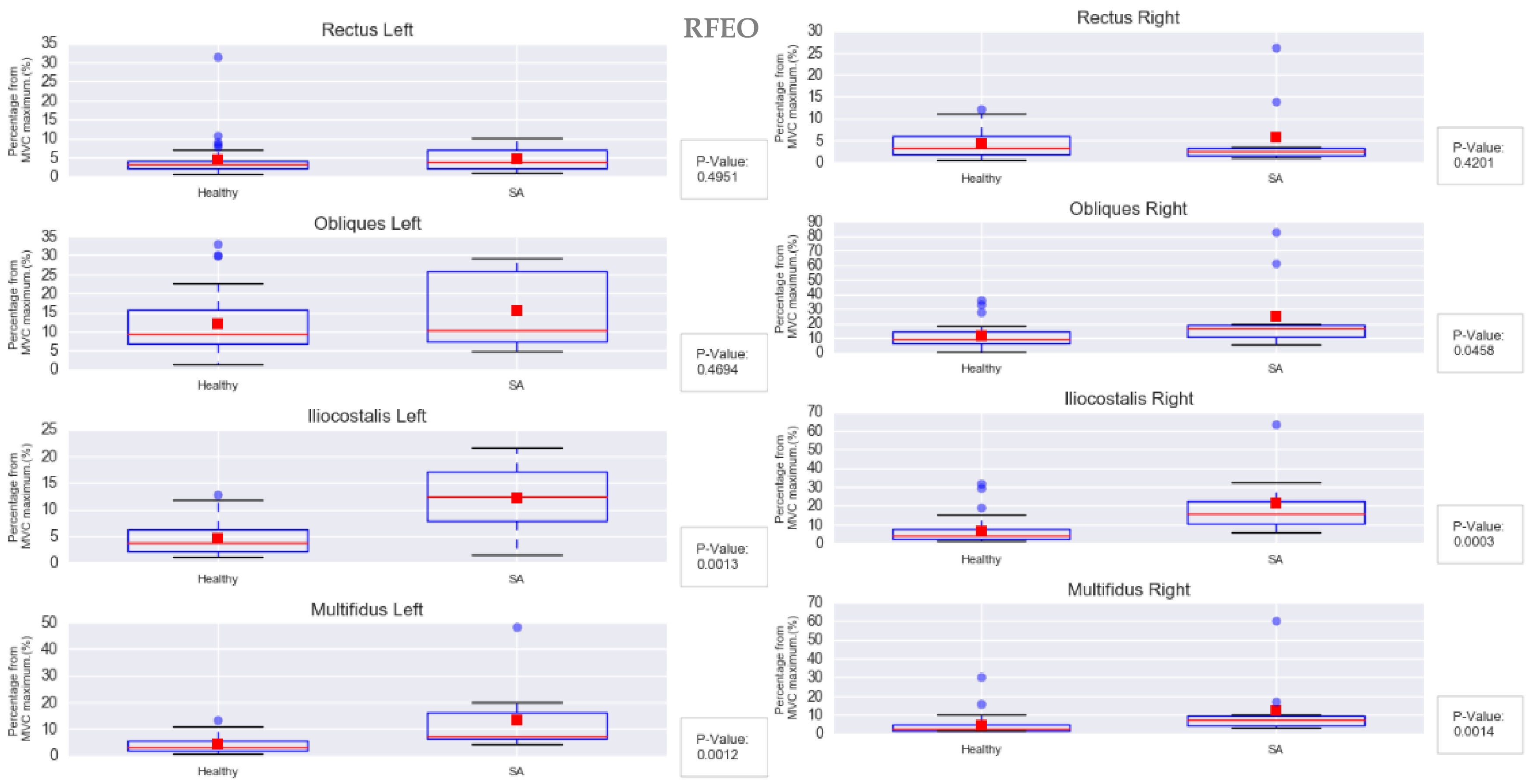


Figure J.1.3 – Boxplot representation of each muscle mean activation for a group of healthy subjects and a group of subjects with ankylosant spondylitis. P-value regarding Mann-Whitney test between the two groups, is represented beside each graphical representation. Graphical representation for RFEO(Right Foot Standing Eyes Open) task.

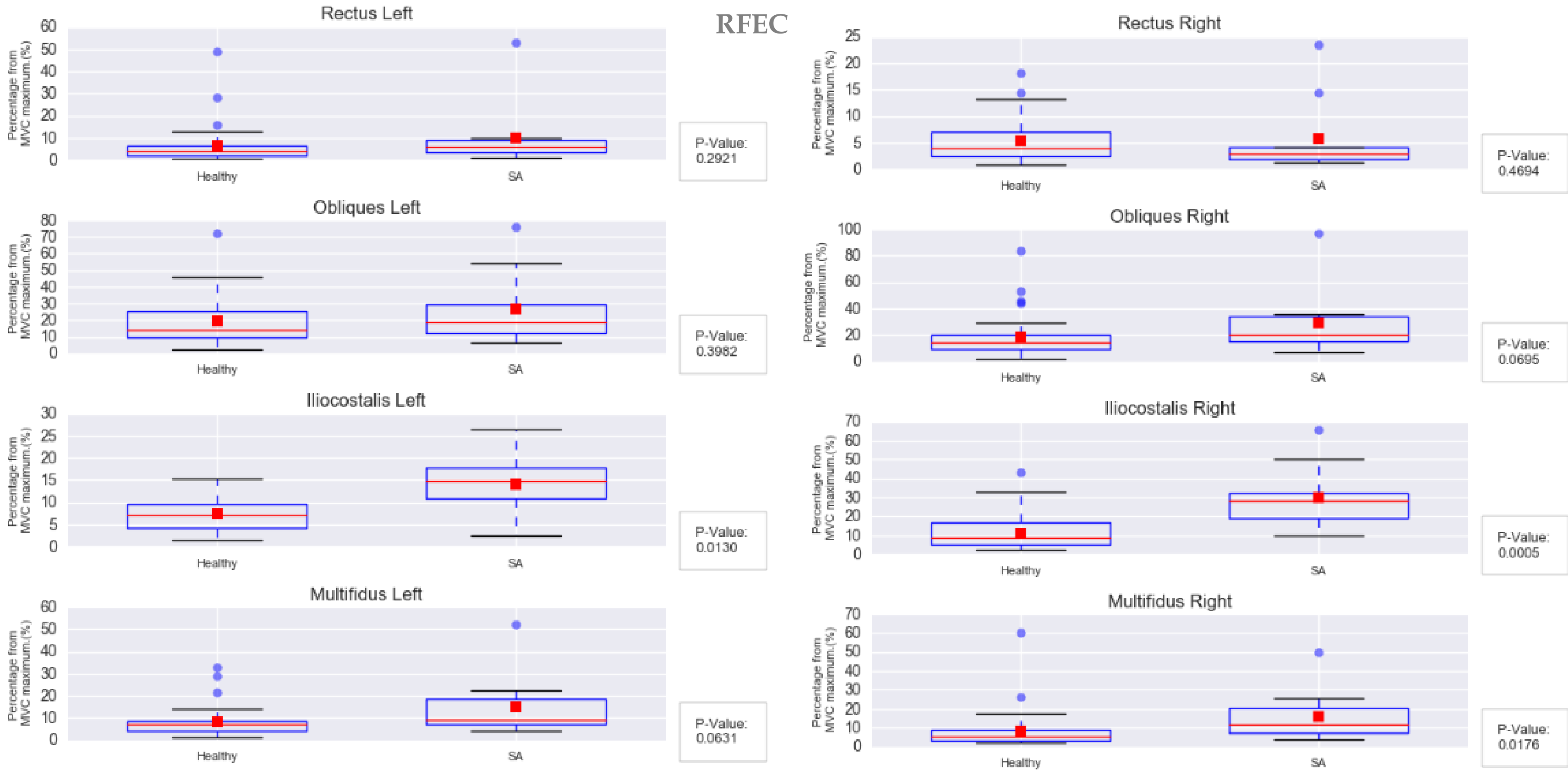


Figure J.1.4 – Boxplot representation of each muscle mean activation for a group of healthy subjects and a group of subjects with ankylosant spondylitis. P-value regarding Mann-Whitney test between the two groups, is represented beside each graphical representation. Graphical representation for RFEC(Right Foot Standing Eyes Close) task.

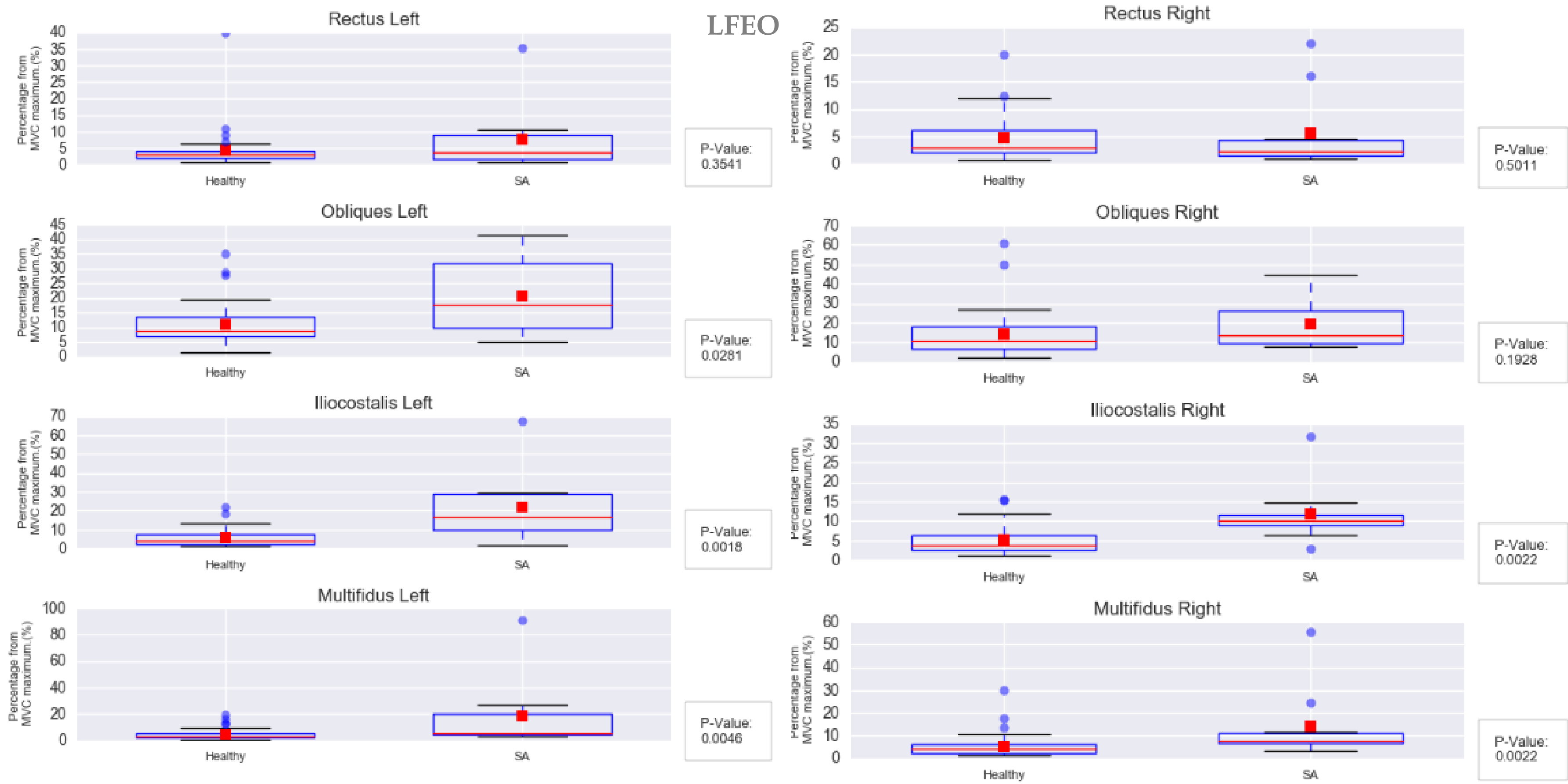


Figure J.1.5 – Boxplot representation of each muscle mean activation for a group of healthy subjects and a group of subjects with ankylosant spondylitis. P-value regarding Mann-Whitney test between the two groups, is represented beside each graphical representation. Graphical representation for LFEO(Left Foot Standing Eyes Open) task.

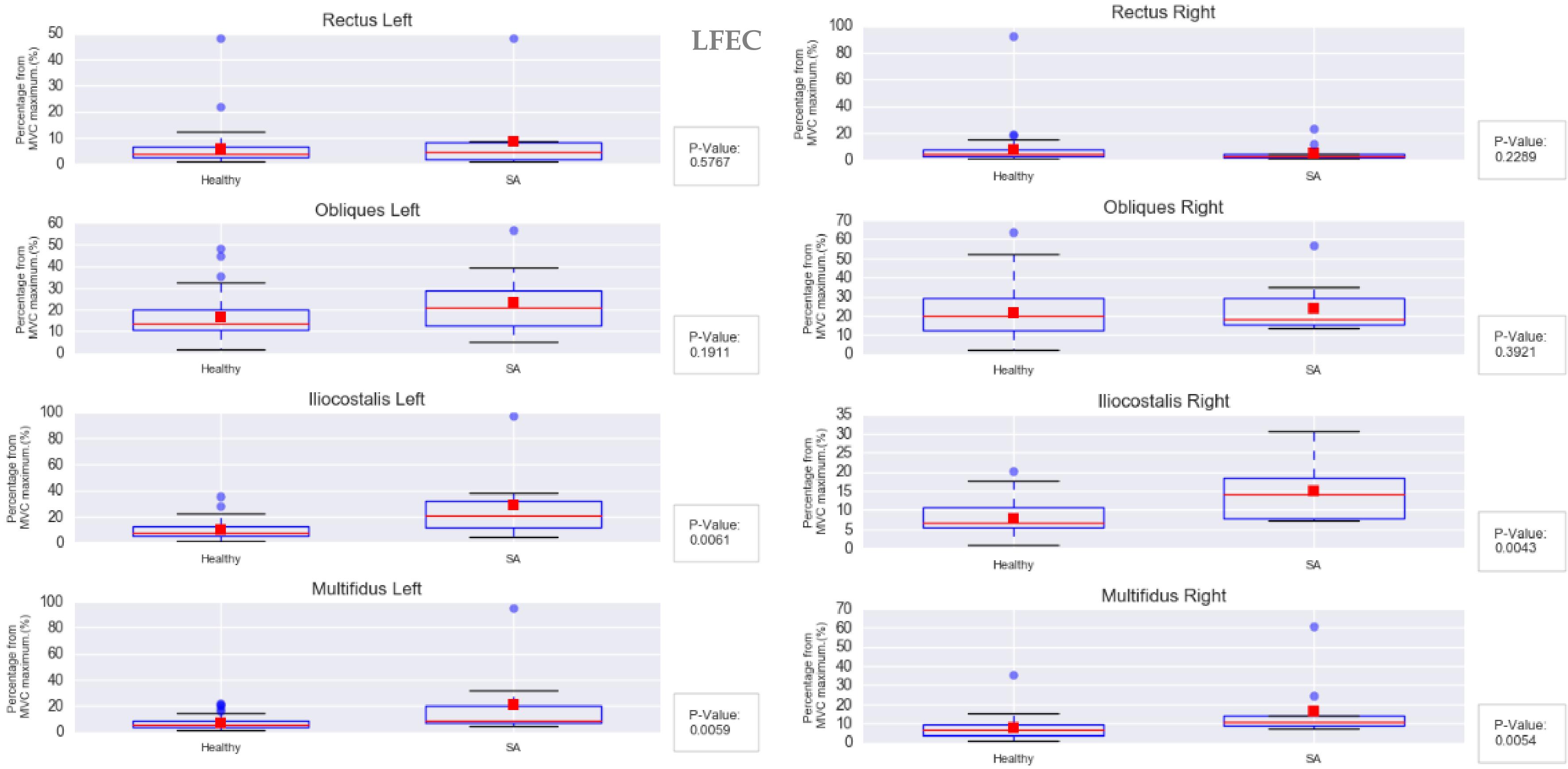


Figure J.1.6 – Boxplot representation of each muscle mean activation for a group of healthy subjects and a group of subjects with ankylosant spondylitis. P-value regarding Mann-Whitney test between the two groups, is represented beside each graphical representation. Graphical representation for LFEC(Left Foot Standing Eyes Close) task.

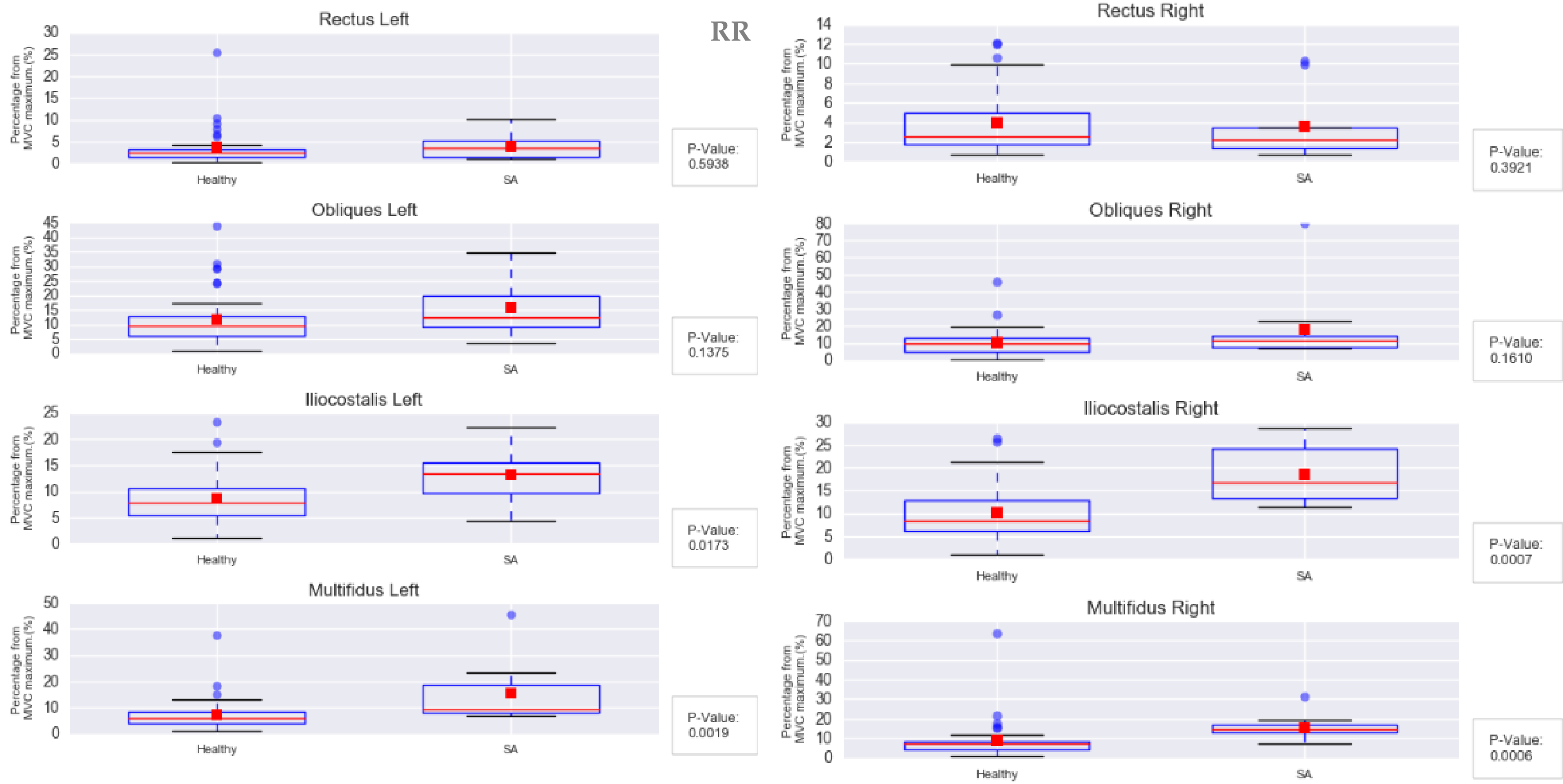


Figure J.1.7 – Boxplot representation of each muscle mean activation for a group of healthy subjects and a group of subjects with ankylosant spondylitis. P-value regarding Mann-Whitney test between the two groups, is represented beside each graphical representation. Graphical representation for RR(Reach Right) task.

RL

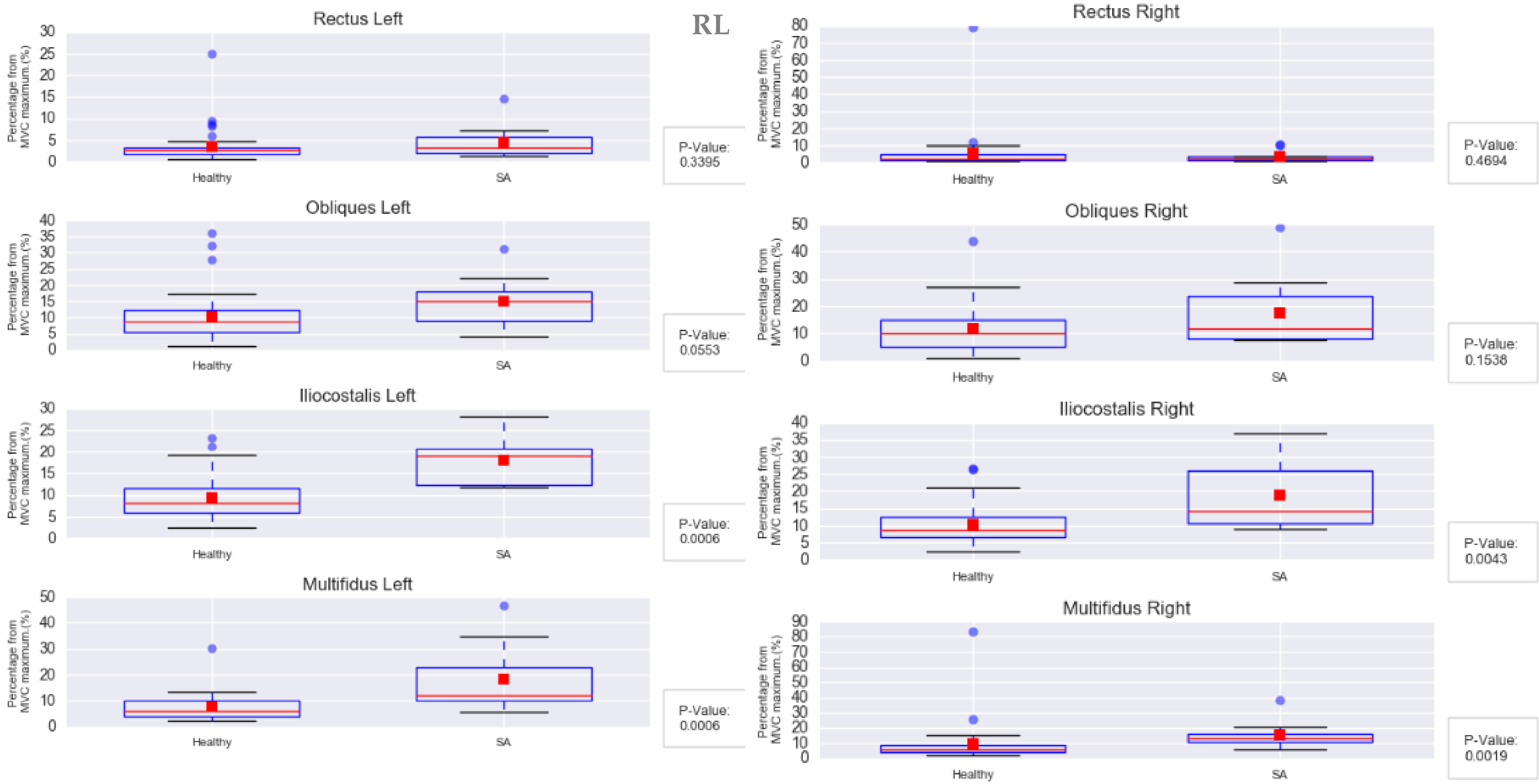


Figure J.1.8 – Boxplot representation of each muscle mean activation for a group of healthy subjects and a group of subjects with ankylosant spondylitis. P-value regarding Mann-Whitney test between the two groups, is represented beside each graphical representation. Graphical representation for RR(Reach Left) task.

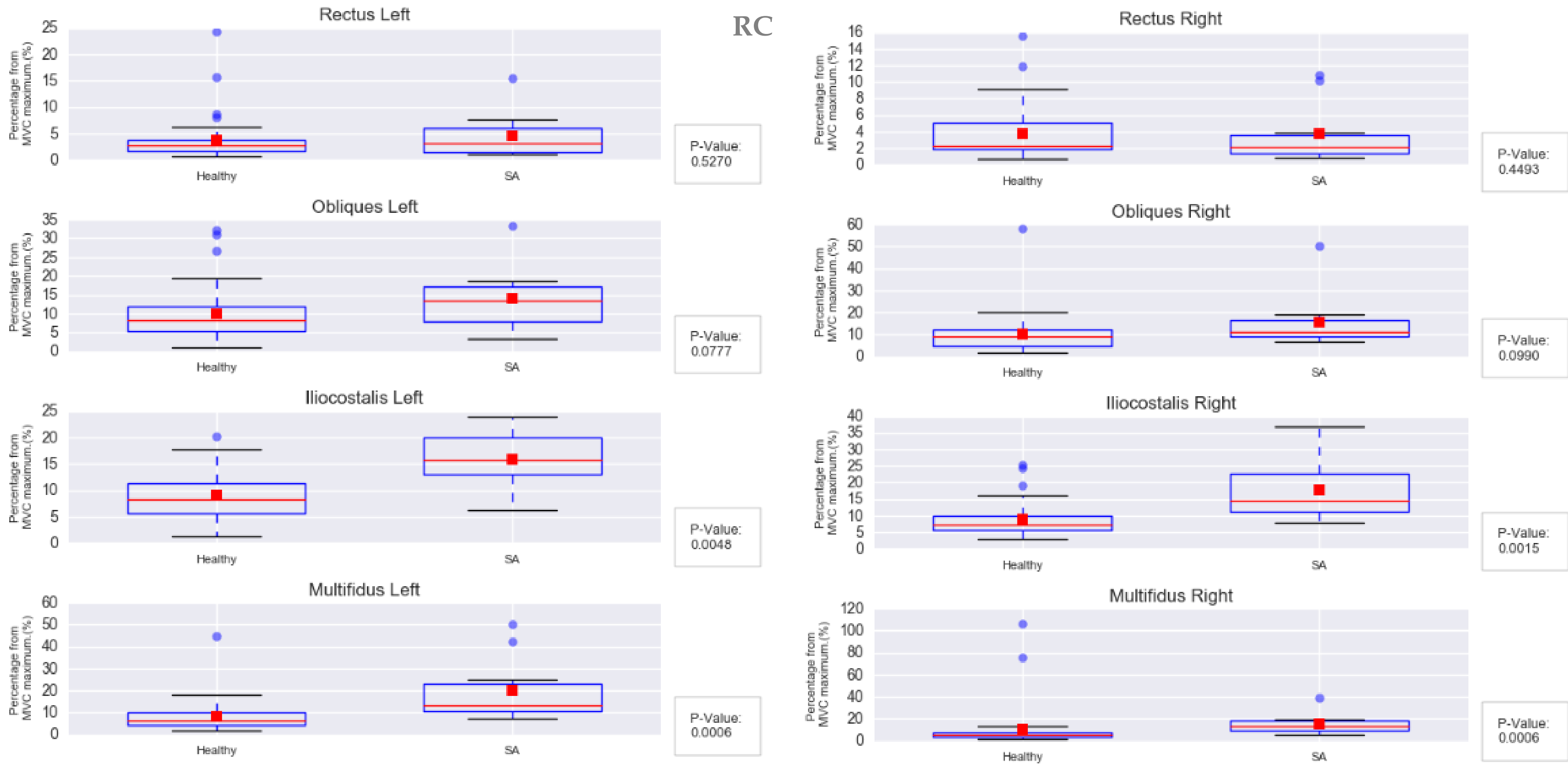
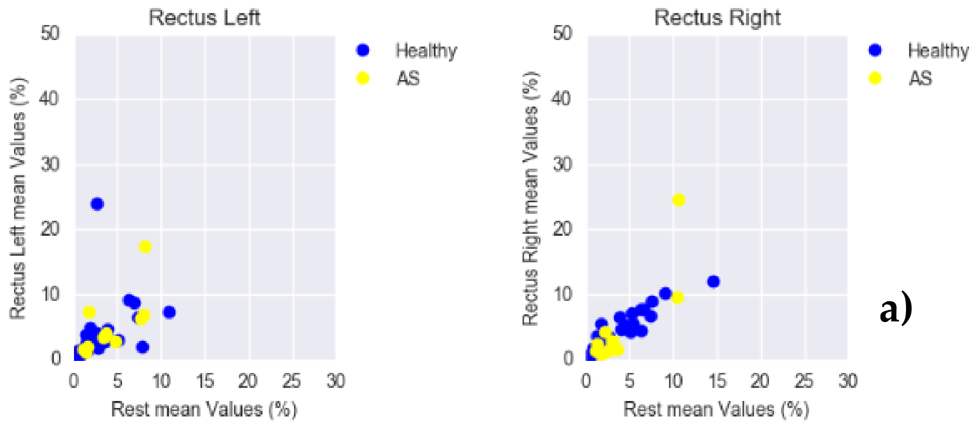


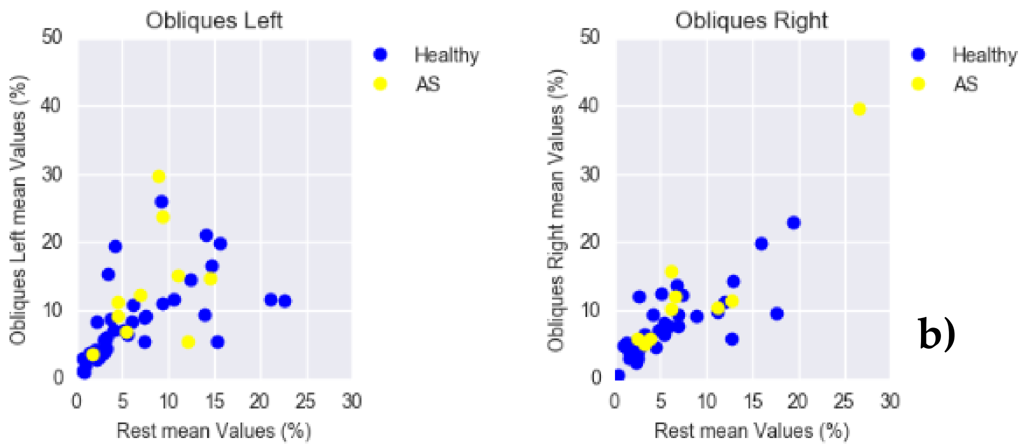
Figure J.1.9 – Boxplot representation of each muscle mean activation for a group of healthy subjects and a group of subjects with ankylosant spondylitis. P-value regarding Mann-Whitney test between the two groups, is represented beside each graphical representation. Graphical representation for RR(Reach Center) task.

J.2 - Muscle Activation during the task VS Muscle activation during rest

SEO



a)



b)

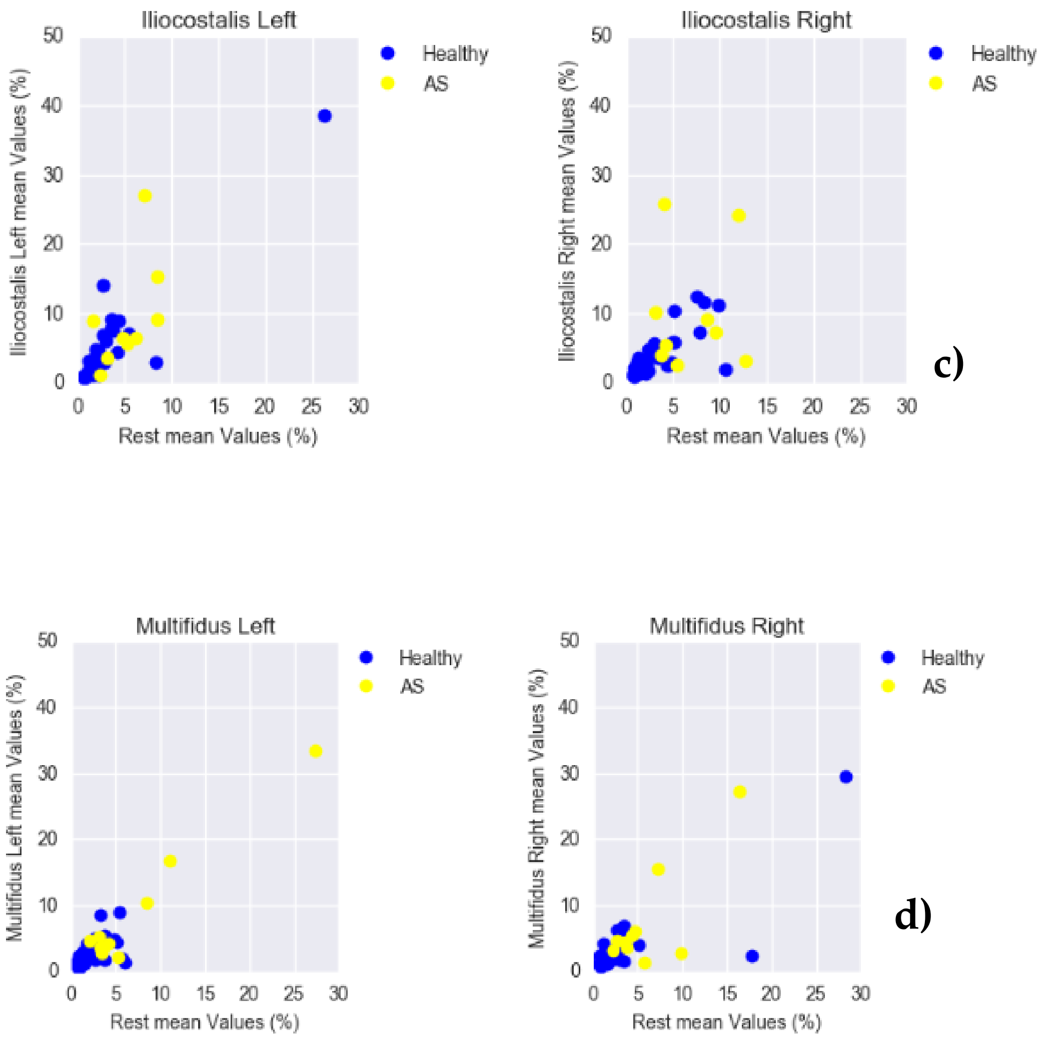
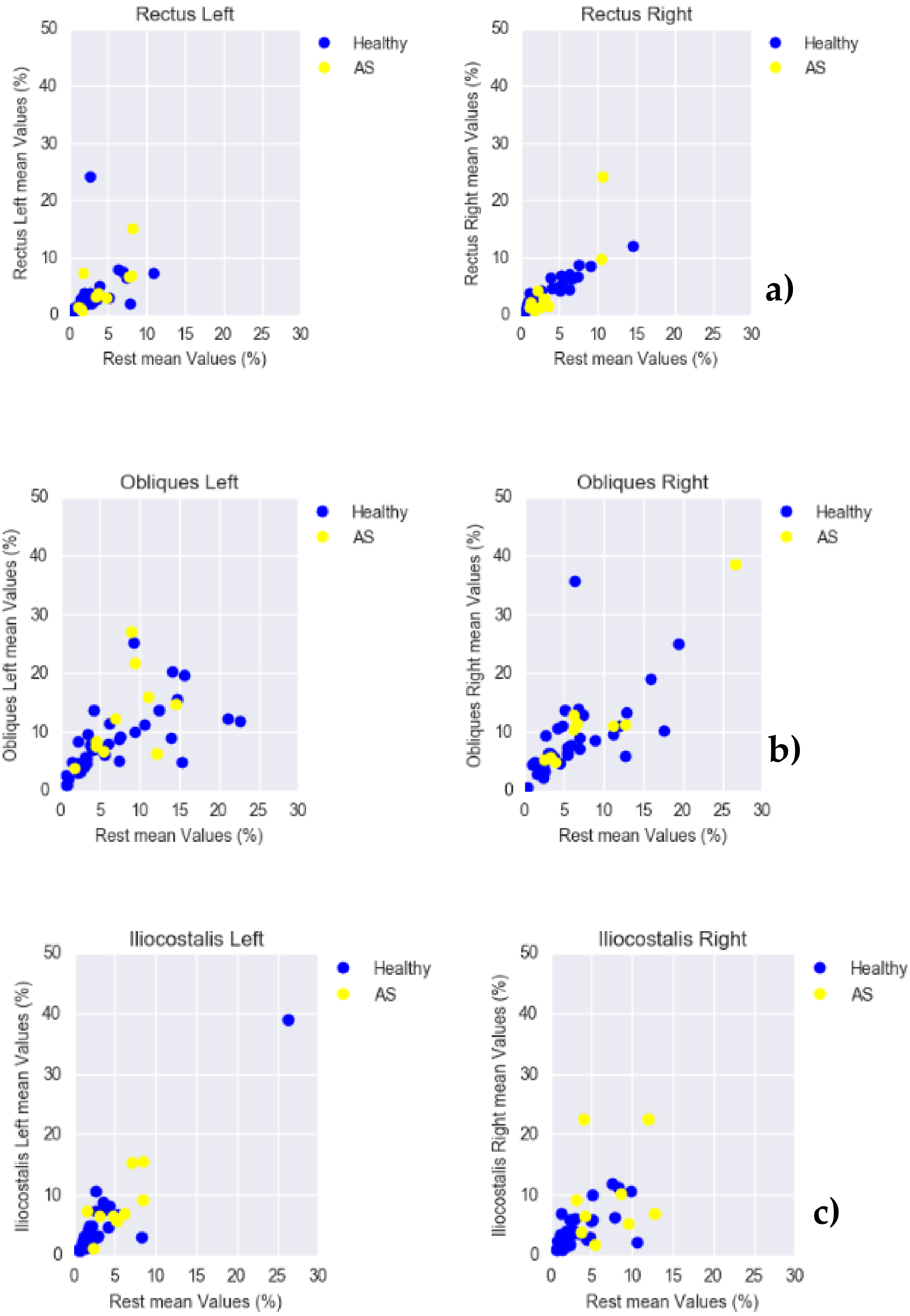


Figure J.2.1 – Mean value of muscle activation during SEO (Standing Eyes Open) task versus mean value of muscle activation during rest. a) Rectus Abdominis Muscles; b) External Obliques Muscles; c) Iliocostalis Muscles; d) Multifidus Muscles.

SEC


Rectus Left
Rectus Right
Obliques Left
Obliques Right
Iliocostalis Left
Iliocostalis Right
Healthy
AS
Rectus Left mean Values (%)
Rectus Right mean Values (%)
Obliques Left mean Values (%)
Obliques Right mean Values (%)
Iliocostalis Left mean Values (%)
Iliocostalis Right mean Values (%)
Rest mean Values (%)
0
5
10
15
20
25
30
40
50
a)
b)
c)

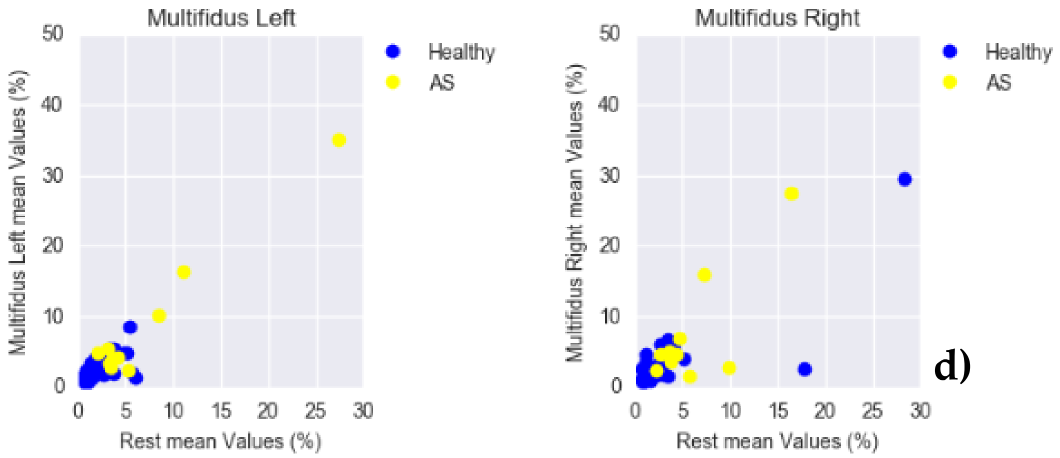
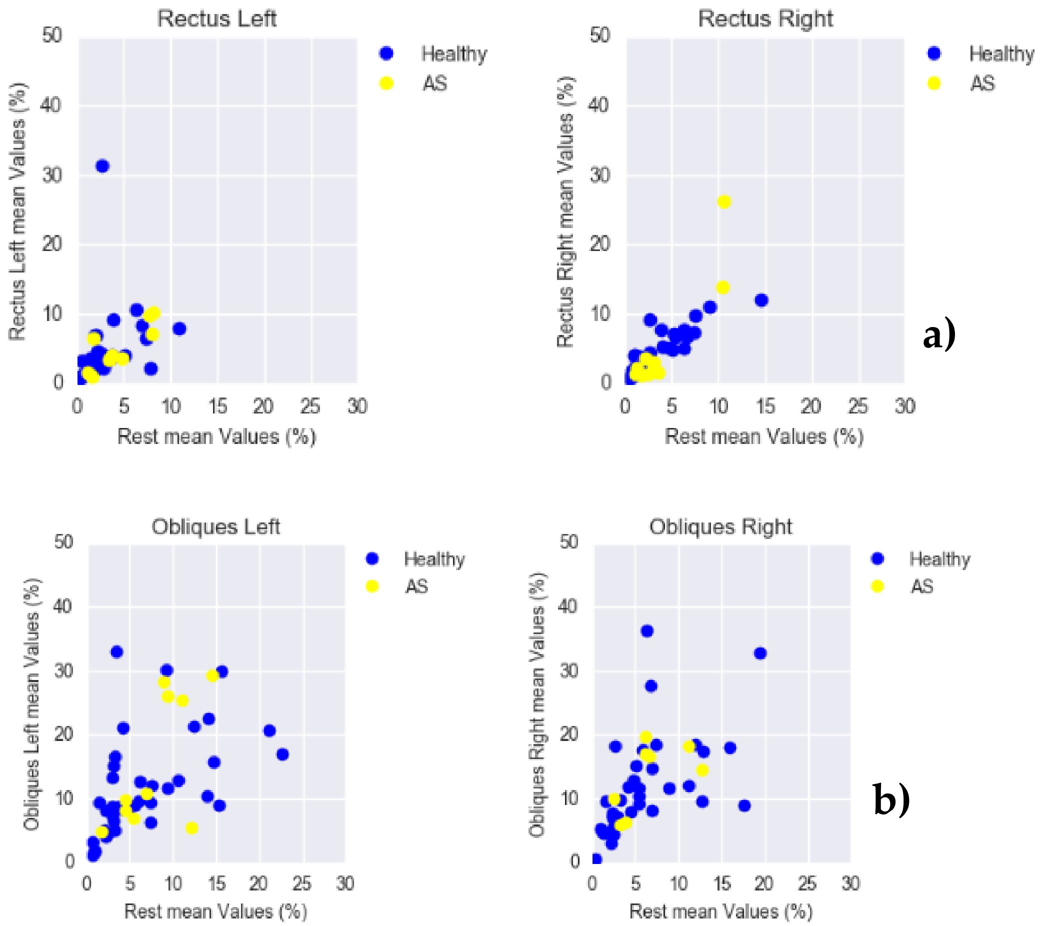


Figure J.2.2 – Mean value of muscle activation during SEC (Standing Eyes Close) task versus mean value of muscle activation during rest. a) Rectus Abdominis Muscles; b) External Obliques Muscles; c) Iliocostalis Muscles; d) Multifidus Muscles.

RFEO



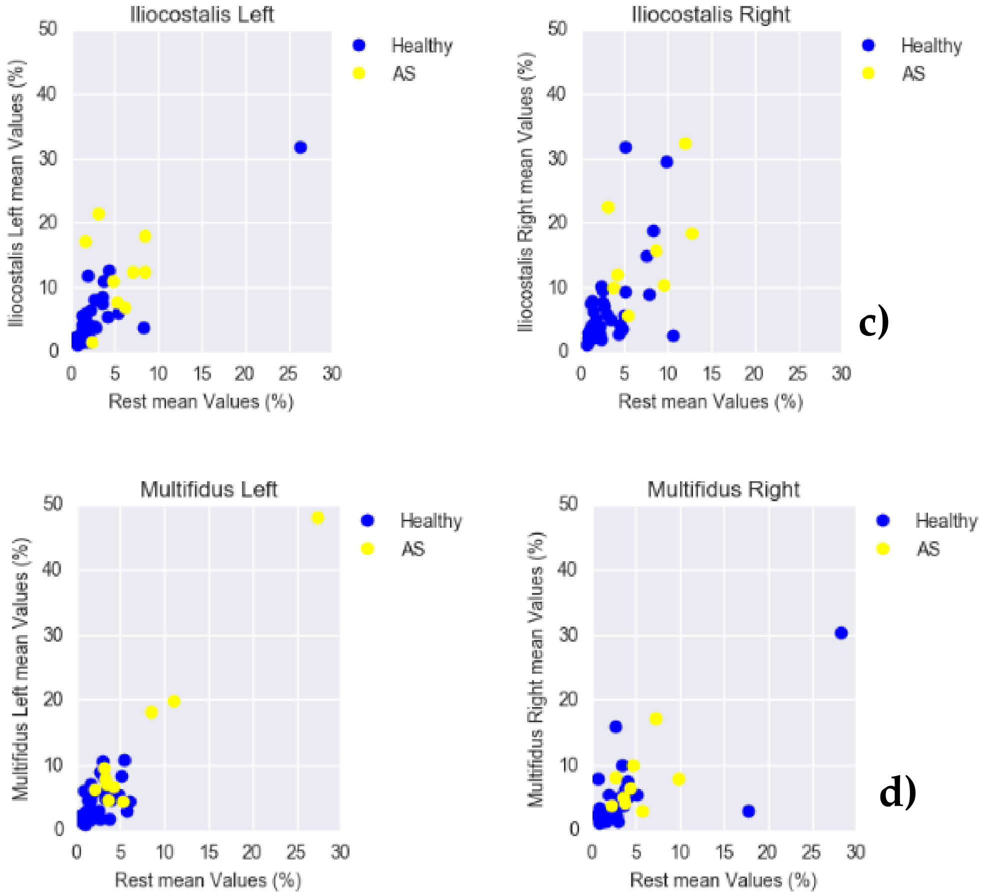
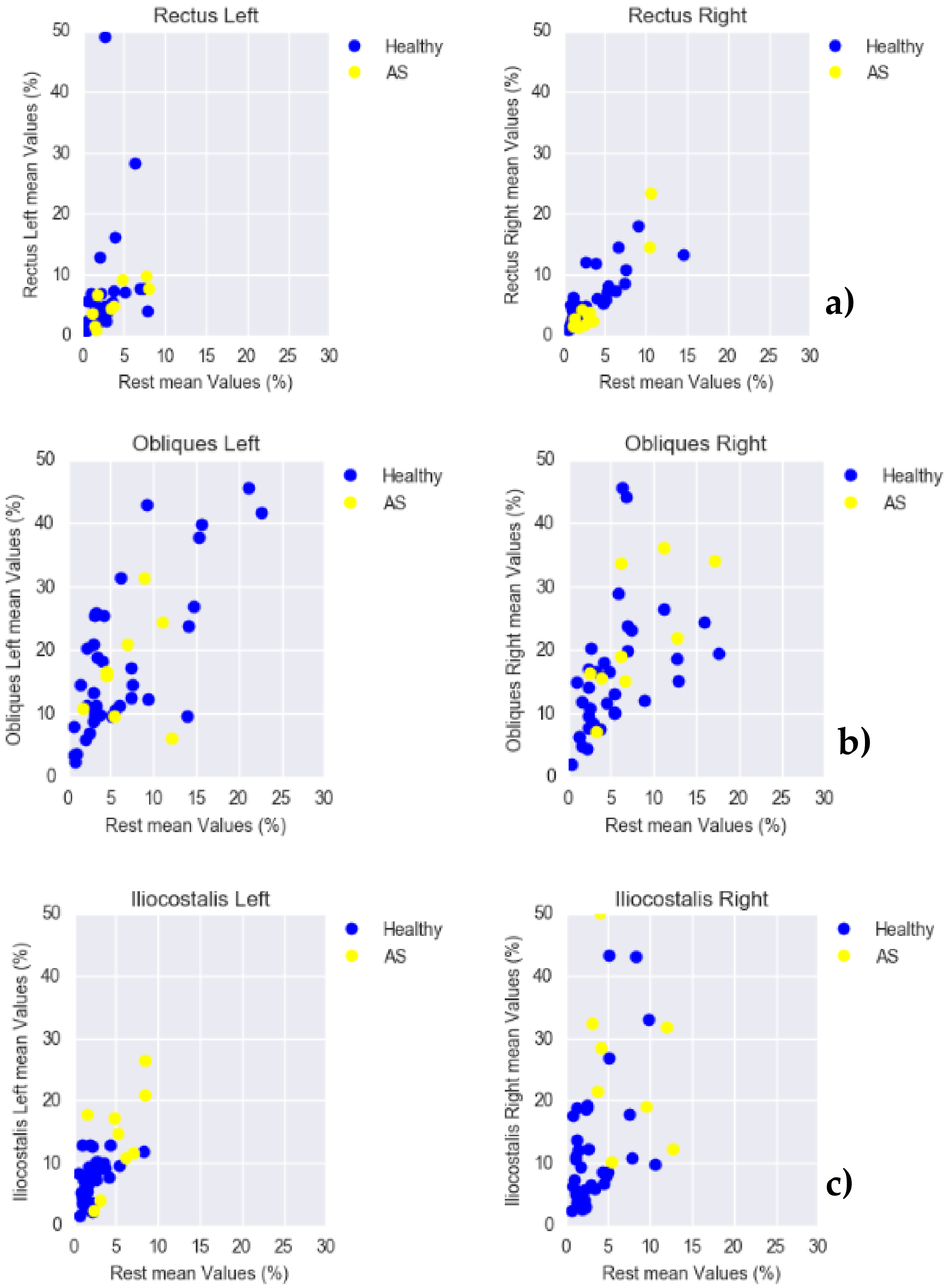


Figure J.2.3 – Mean value of muscle activation during RFEO (Right Foot Eyes Open) task versus mean value of muscle activation during rest. a) Rectus Abdominis Muscles; b) External Obliques Muscles; c) Iliocostalis Muscles; d) Multifidus Muscles.


Rectus Left
Rectus Right
Healthy
AS
a)
Obliques Left
Obliques Right
b)
Iliocostalis Left
Iliocostalis Right
c)
Rest mean Values (%)
Rectus Left mean Values (%)
Rectus Right mean Values (%)
Obliques Left mean Values (%)
Obliques Right mean Values (%)
Iliocostalis Left mean Values (%)
Iliocostalis Right mean Values (%)

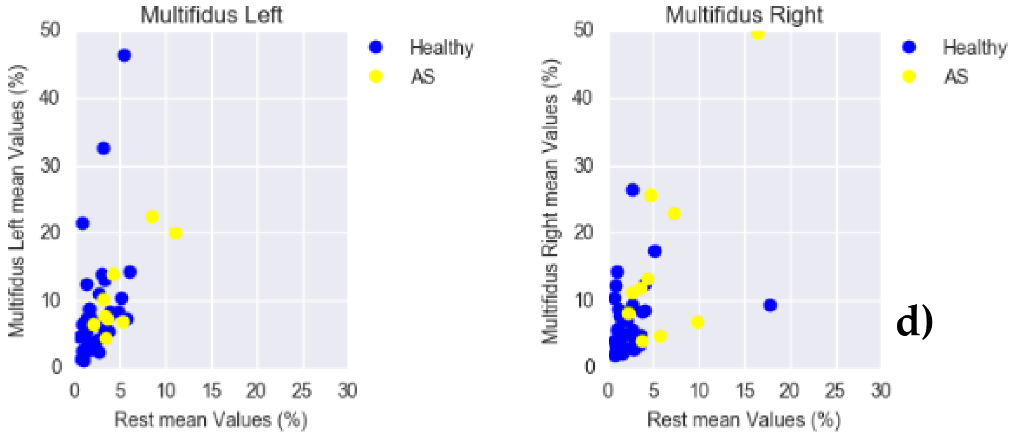
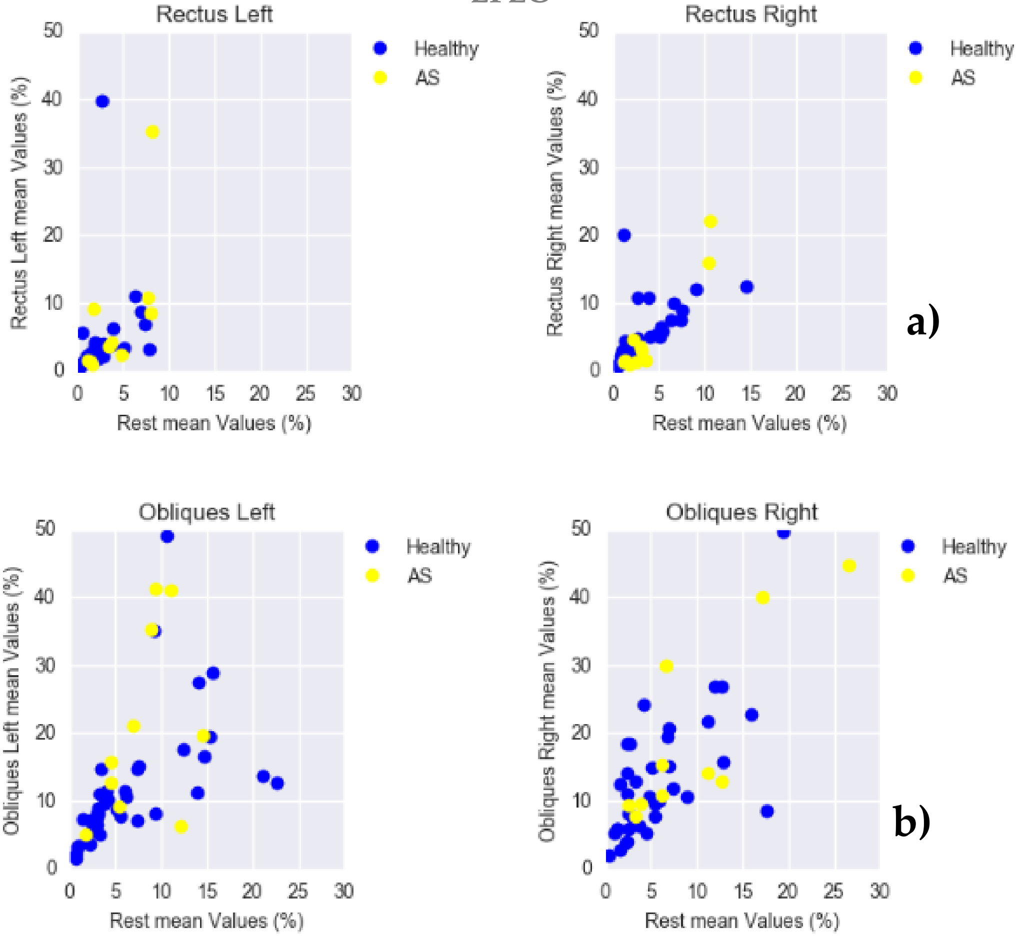


Figure J.2.4 – Mean value of muscle activation during RFEC (Right Foot Eyes Close) task versus mean value of muscle activation during rest. a) Rectus Abdominis Muscles; b) External Obliques Muscles; c) Iliocostalis Muscles; d) Multifidus Muscles.

LFEO



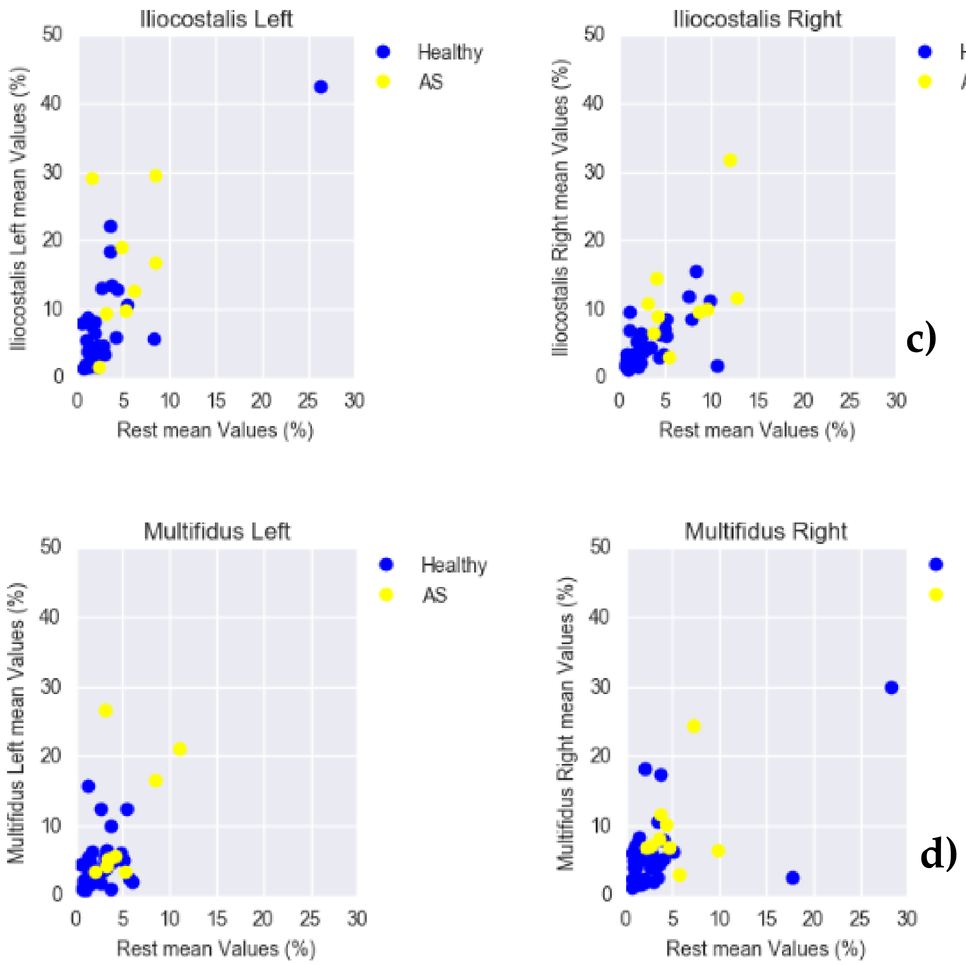
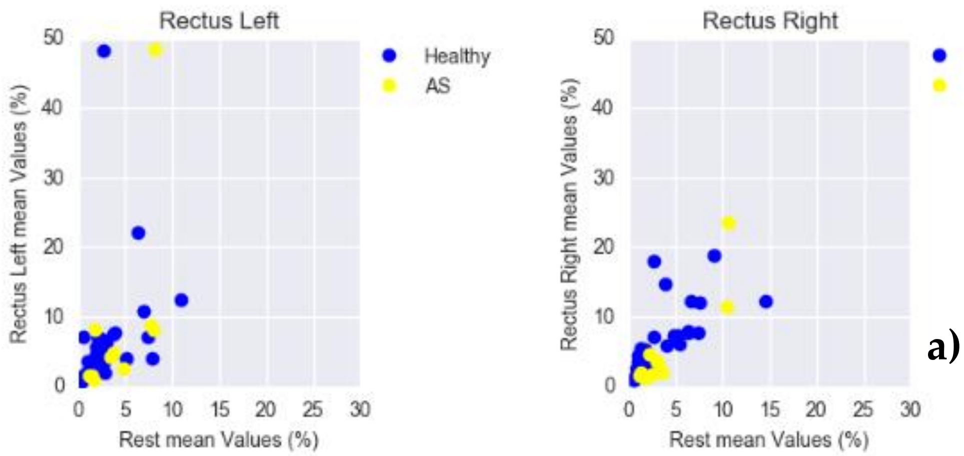


Figure J.2.5 – Mean value of muscle activation during LFEO (Left Foot Eyes Open) task versus mean value of muscle activation during rest. a) Rectus Abdominis Muscles; b) External Obliques Muscles; c) Iliocostalis Muscles; d) Multifidus Muscles.

LFEC



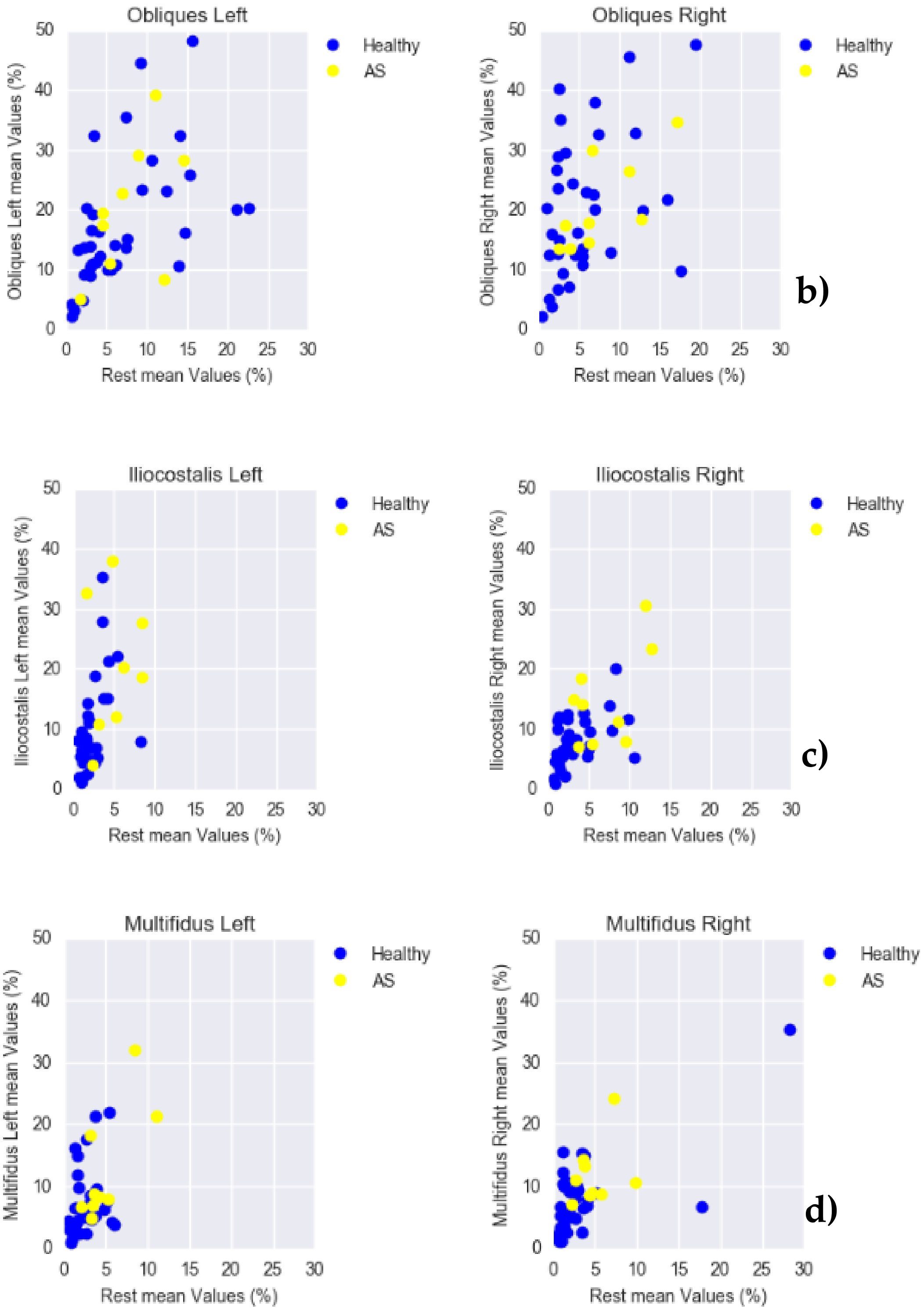
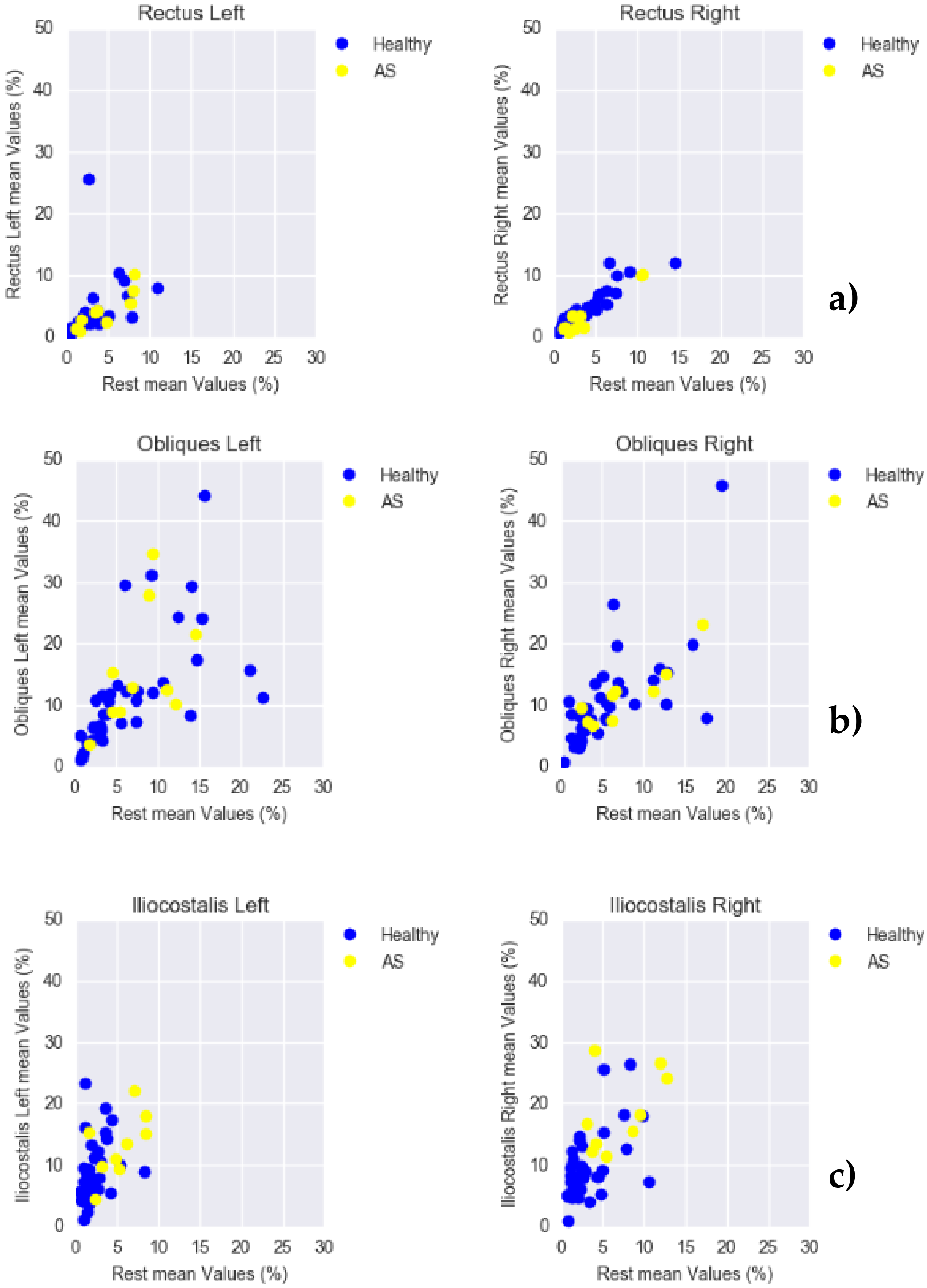


Figure J.2.6 – Mean value of muscle activation during LFEC (Left Foot Eyes Close) task versus mean value of muscle activation during rest. a) Rectus Abdominis Muscles; b) External Obliques Muscles; c) Iliocostalis Muscles; d) Multifidus Muscles.

RR



Rectus Left
Rectus Left mean Values (%)
Rest mean Values (%)
Healthy
AS
Rectus Right
Rectus Right mean Values (%)
Rest mean Values (%)
Healthy
AS
a)
Obliques Left
Obliques Left mean Values (%)
Rest mean Values (%)
Healthy
AS
Obliques Right
Obliques Right mean Values (%)
Rest mean Values (%)
Healthy
AS
b)
Iliocostalis Left
Iliocostalis Left mean Values (%)
Rest mean Values (%)
Healthy
AS
Iliocostalis Right
Iliocostalis Right mean Values (%)
Rest mean Values (%)
Healthy
AS
c)

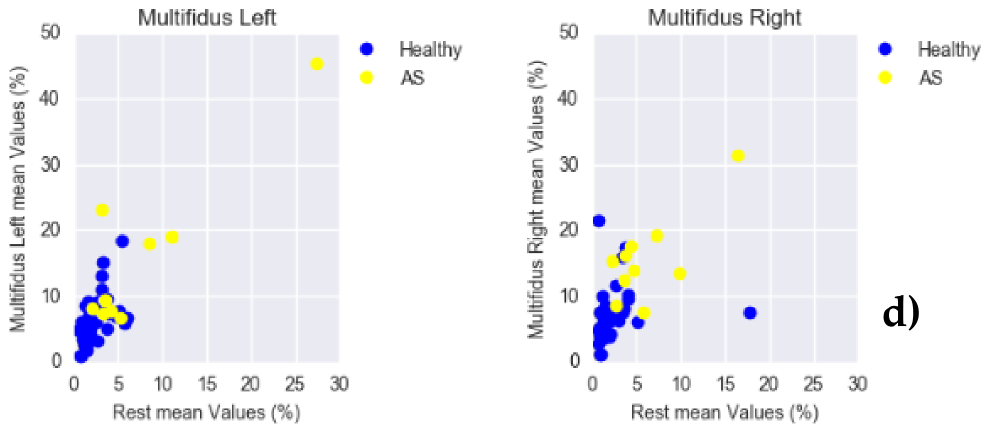
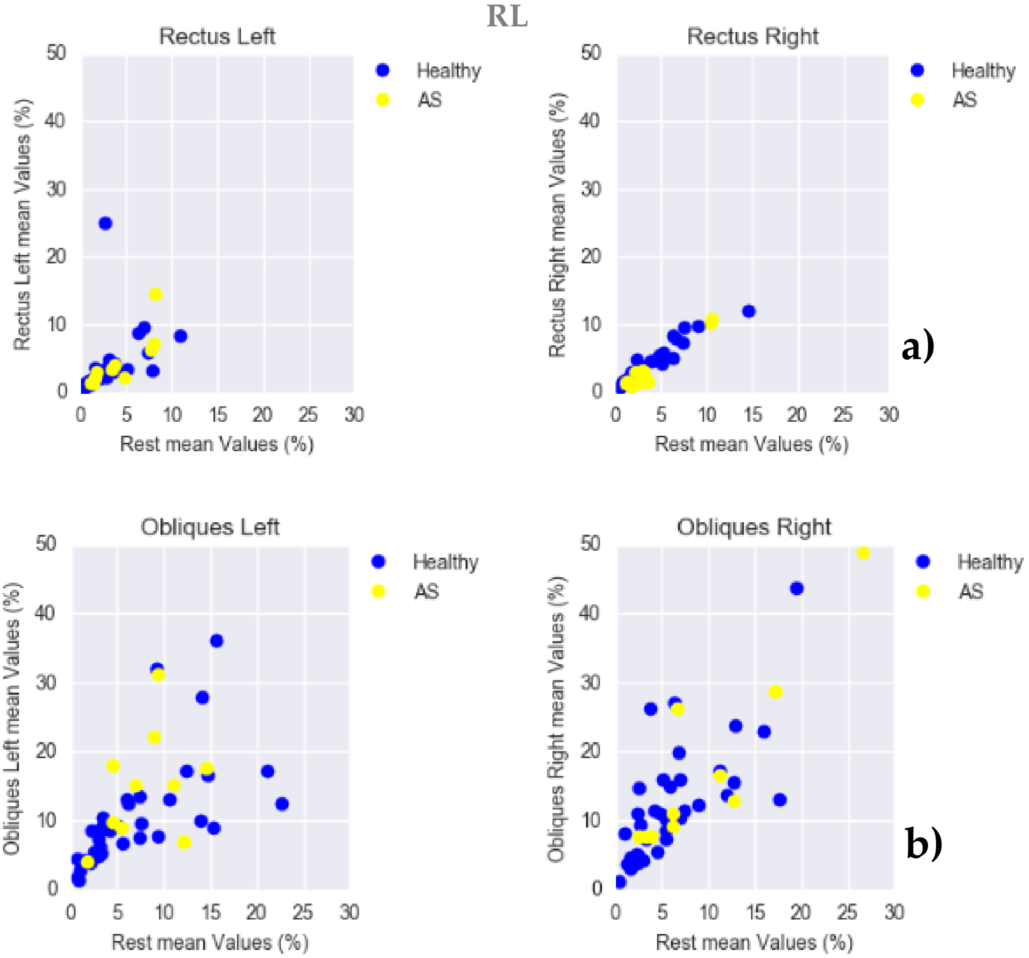


Figure J.2.7 – Mean value of muscle activation during RR (Reach Right) task versus mean value of muscle activation during rest. a) Rectus Abdominis Muscles; b) External Obliques Muscles; c) Iliocostalis Muscles; d) Multifidus Muscles.

RL



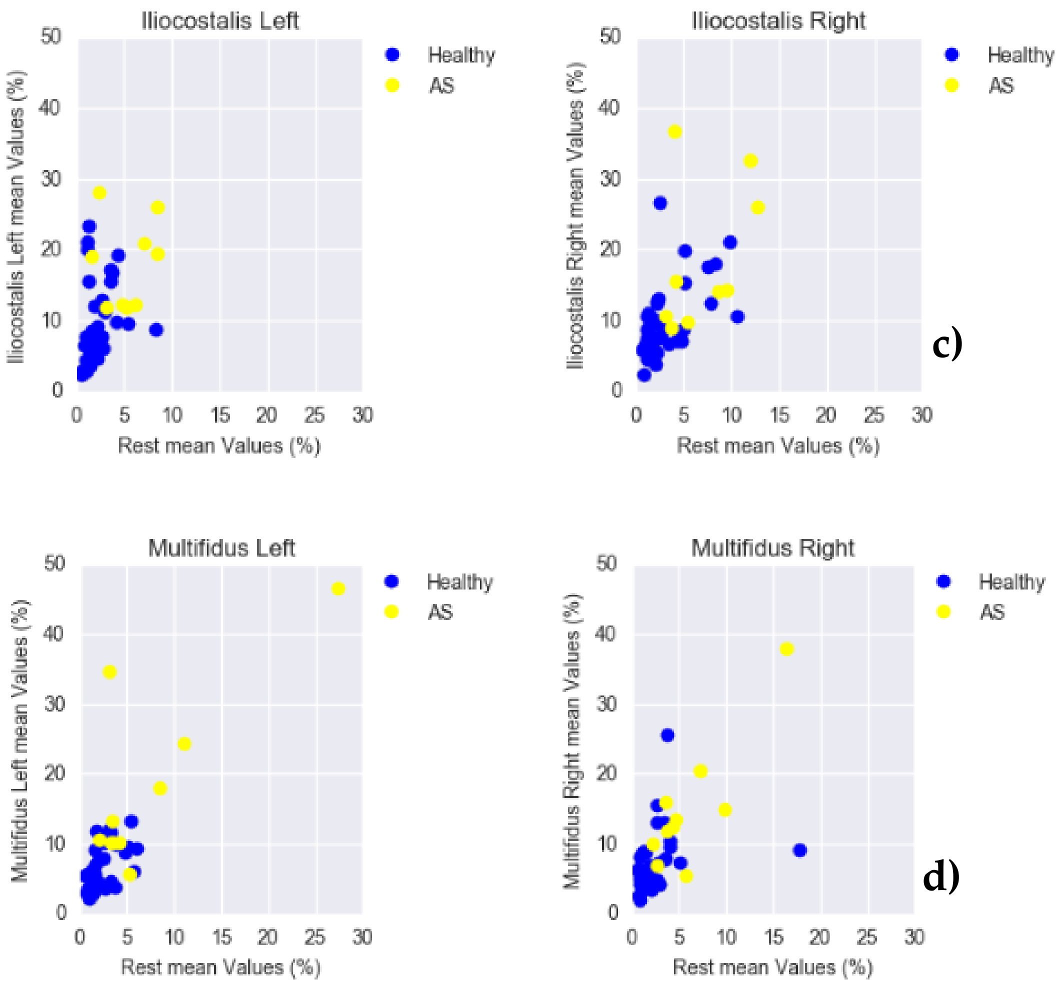
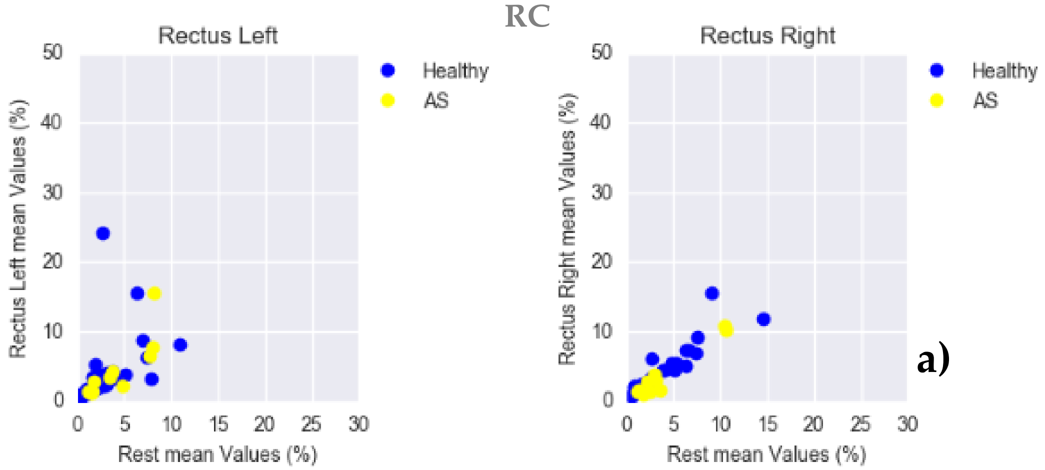


Figure J.2.8 – Mean value of muscle activation during RL (Reach Left) task versus mean value of muscle activation during rest. a) Rectus Abdominis Muscles; b) External Obliques Muscles; c) Iliocostalis Muscles; d) Multifidus Muscles.

RC



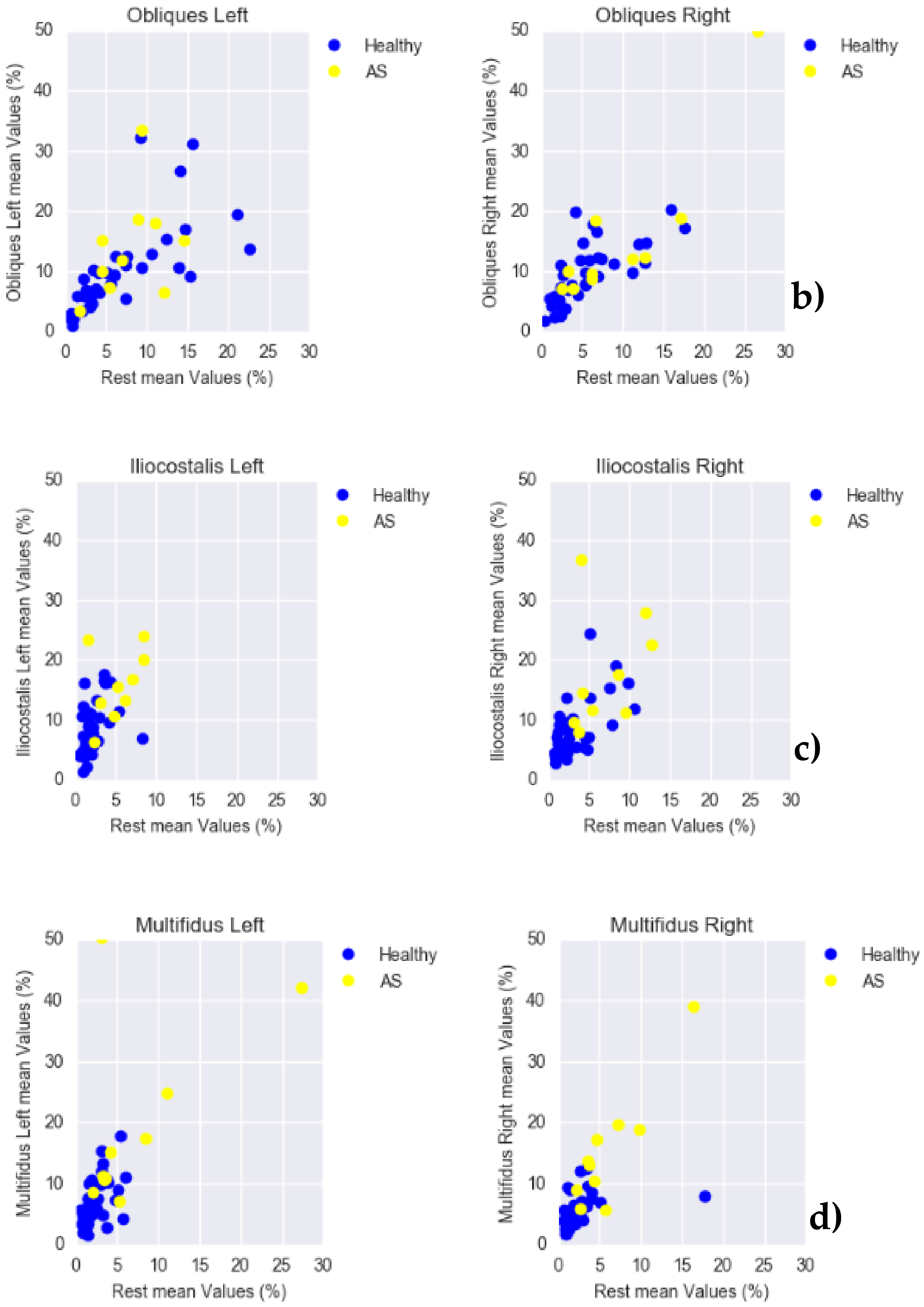
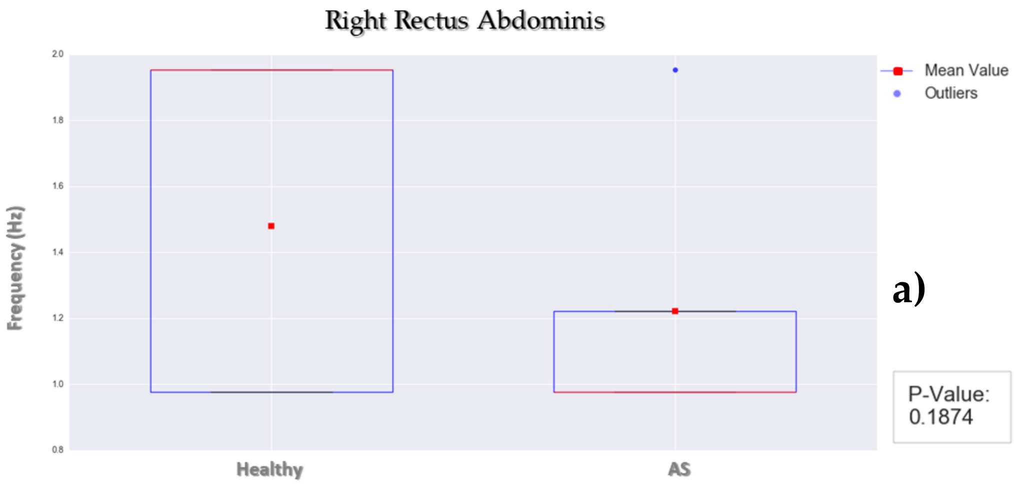
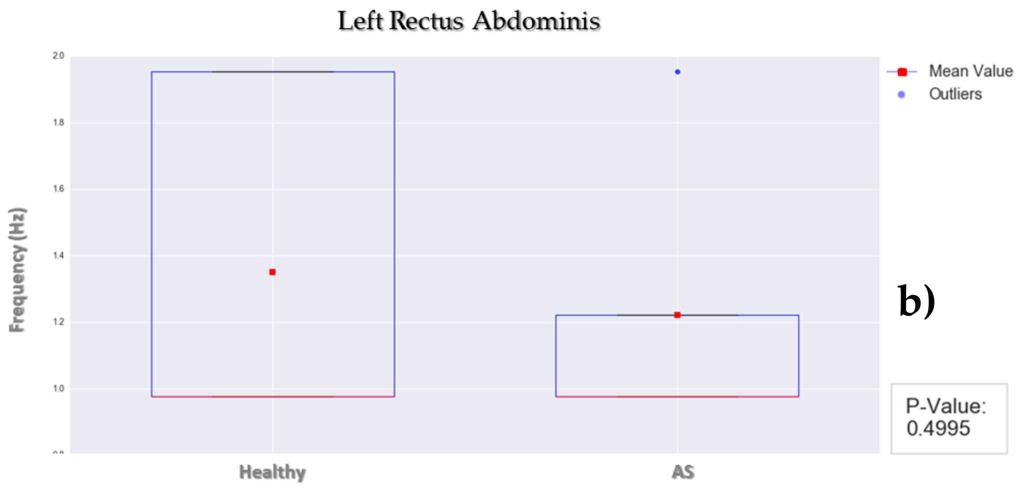


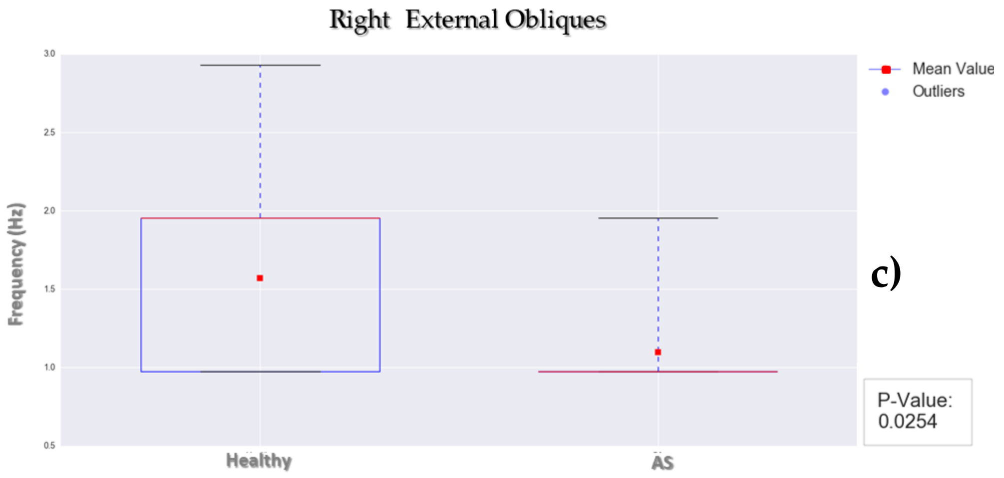
Figure J.2.9 – Mean value of muscle activation during RC (Reach Center) task versus mean value of muscle activation during rest. a) Rectus Abdominis Muscles; b) External Obliques Muscles; c) Iliocostalis Muscles; d) Multifidus Muscles.

J.3 – EMG Frequency during rest

Peak Frequency

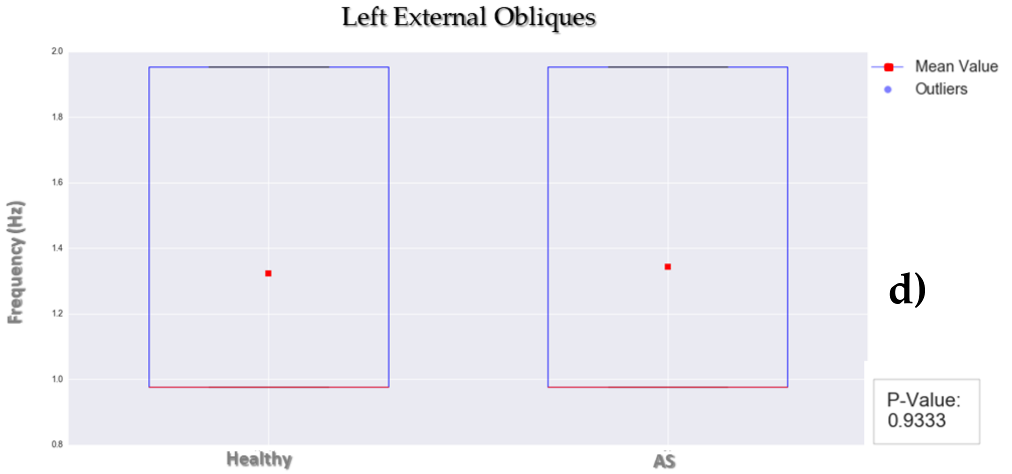






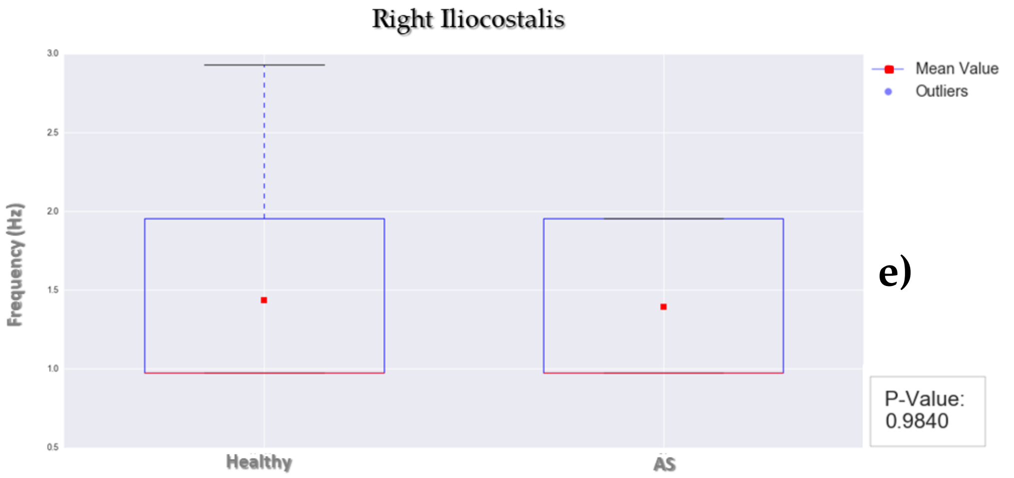
Right External Obliques
Frequency (Hz)
Healthy
AS
Mean Value
Outliers
P-Value:
0.0254

c)



Left External Obliques
Frequency (Hz)
Healthy
AS
Mean Value
Outliers
P-Value:
0.9333

d)



Right Iliocostalis
Frequency (Hz)
Healthy
AS
Mean Value
Outliers
P-Value:
0.9840

e)

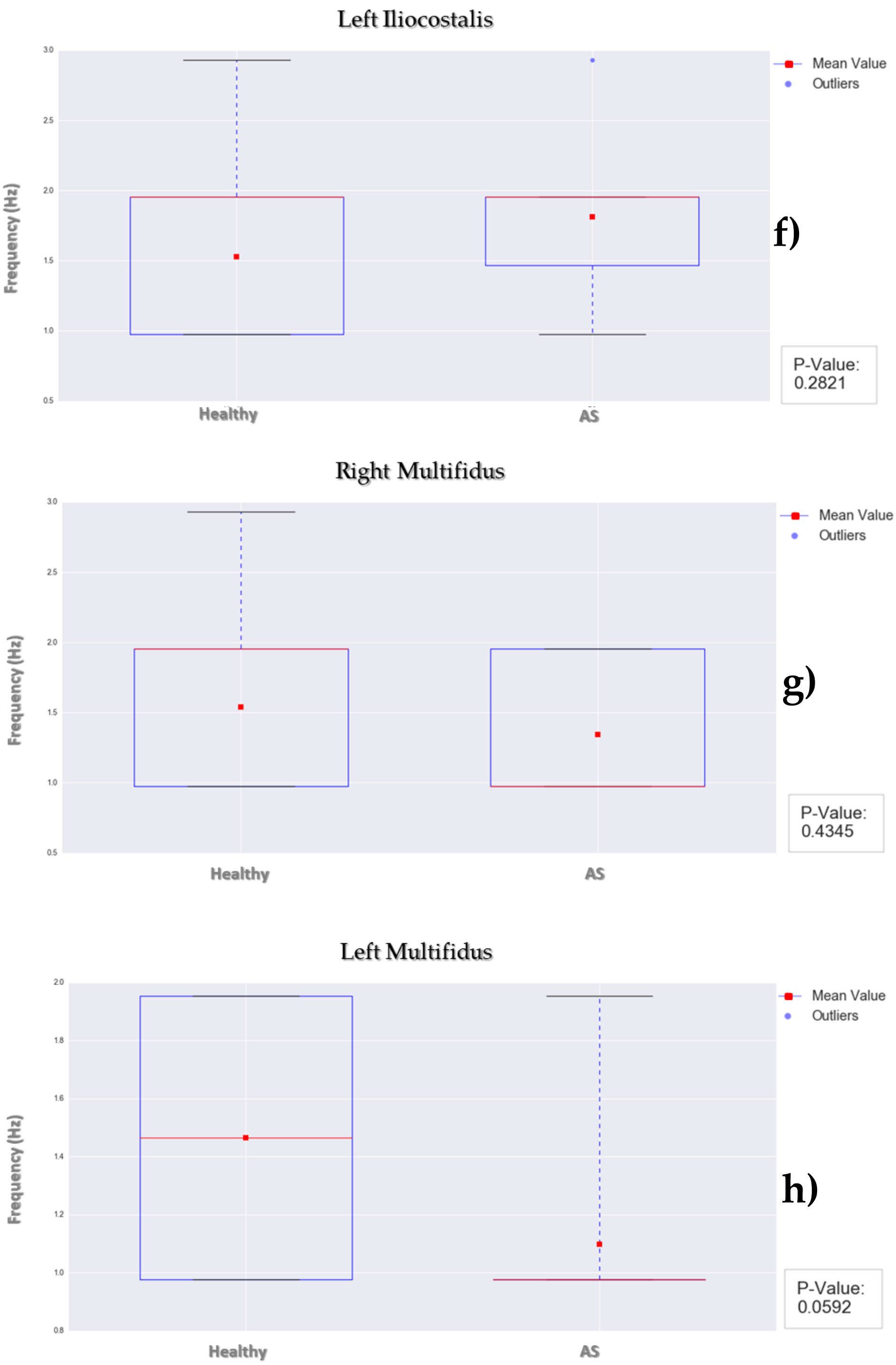
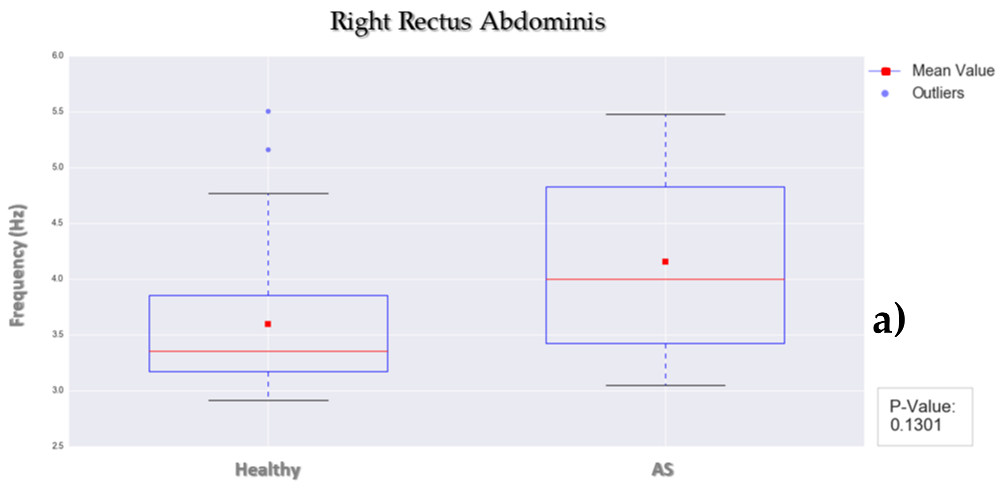
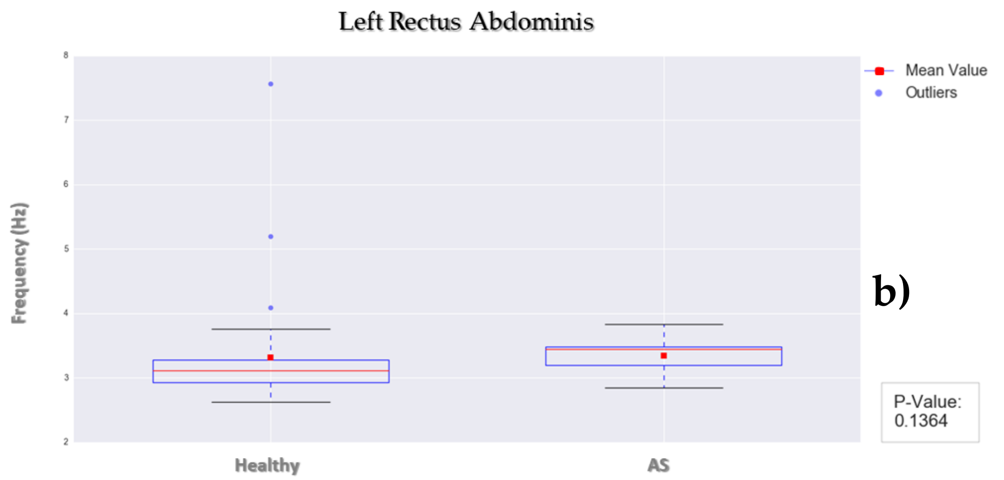
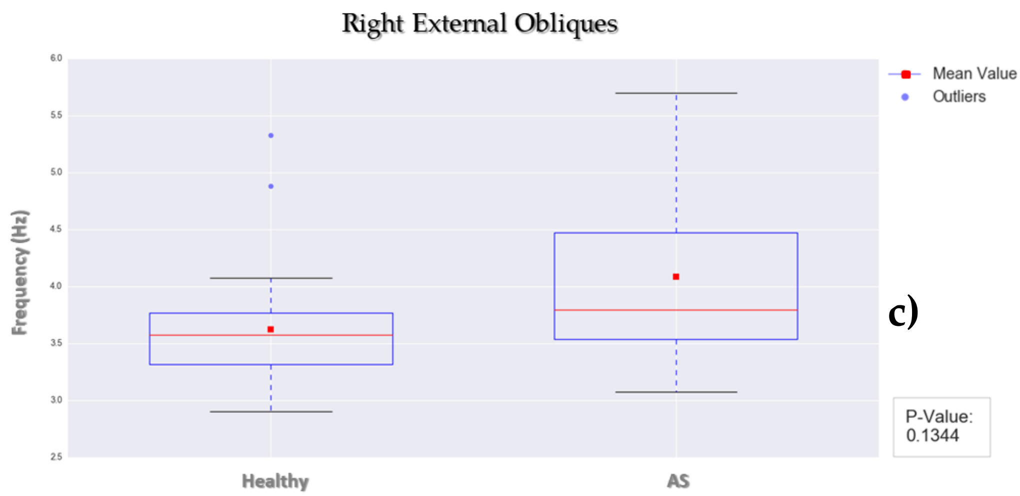


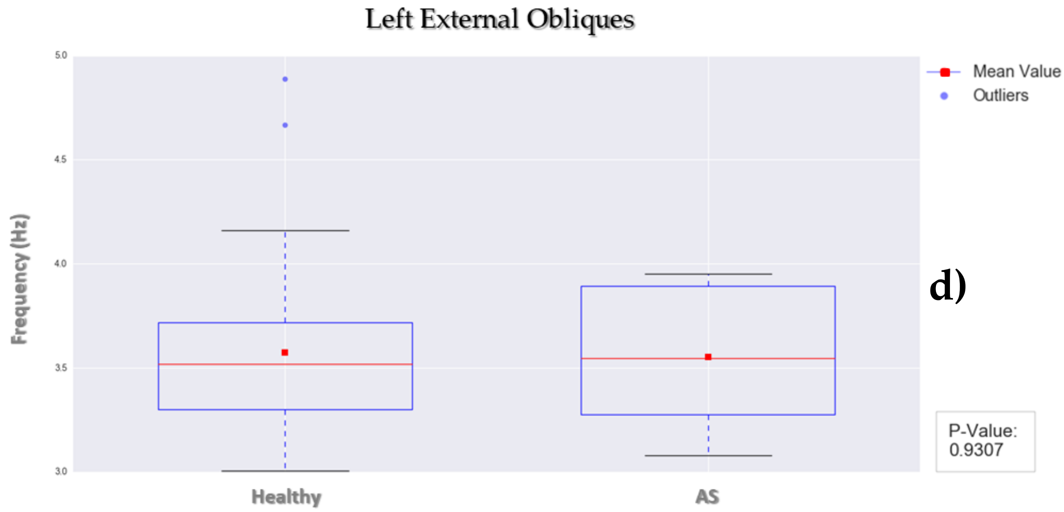
Figure J.3.1 – Peak frequency during rest for each muscle in evaluation. a) Right Rectus Abdominis; b) Left Rectus Abdominis; c) Right External Obliques; d) Left External Obliques; e) Right Iliocostalis; f) Left Iliocostalis; g) Right Multifidus; h) Left Multifidus.

Mean Frequency

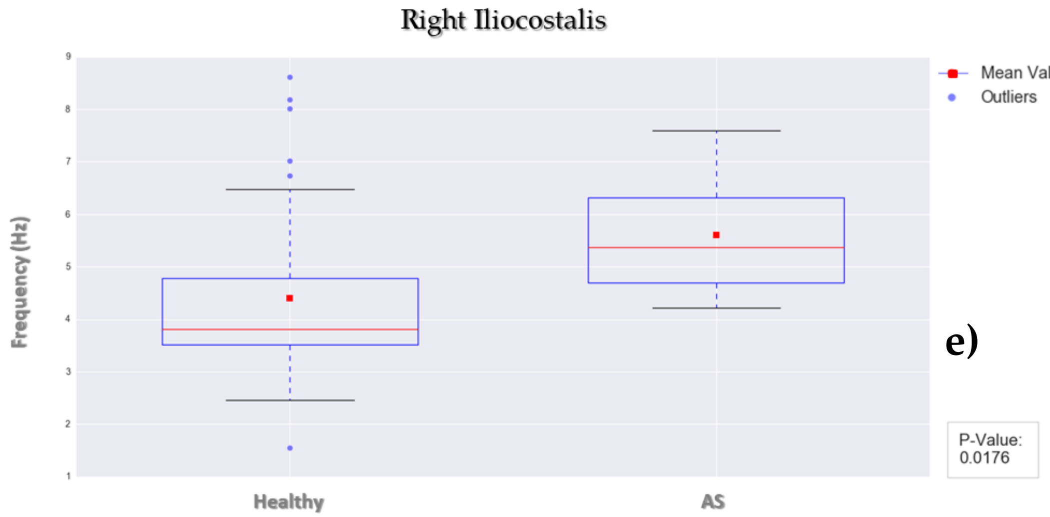




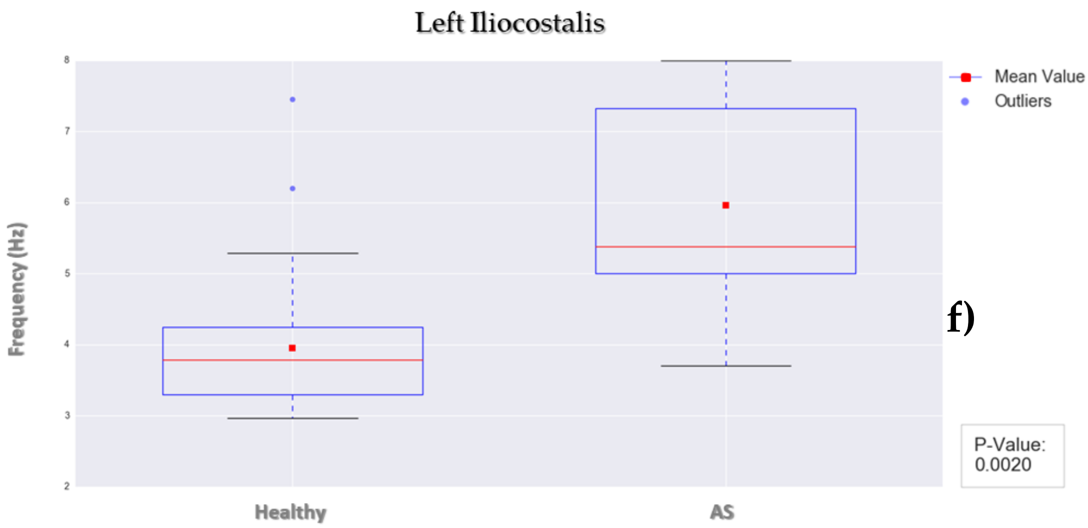



Left External Obliques
Frequency (Hz)
5.0
4.5
4.0
3.5
3.0
Healthy
AS
Mean Value
Outliers
P-Value:
0.9307

d)


Right Iliocostalis
Frequency (Hz)
9
8
7
6
5
4
3
2
1
Healthy
AS
Mean Value
Outliers
P-Value:
0.0176

e)


Left Iliocostalis
Frequency (Hz)
8
7
6
5
4
3
2
Healthy
AS
Mean Value
Outliers
P-Value:
0.0020

f)

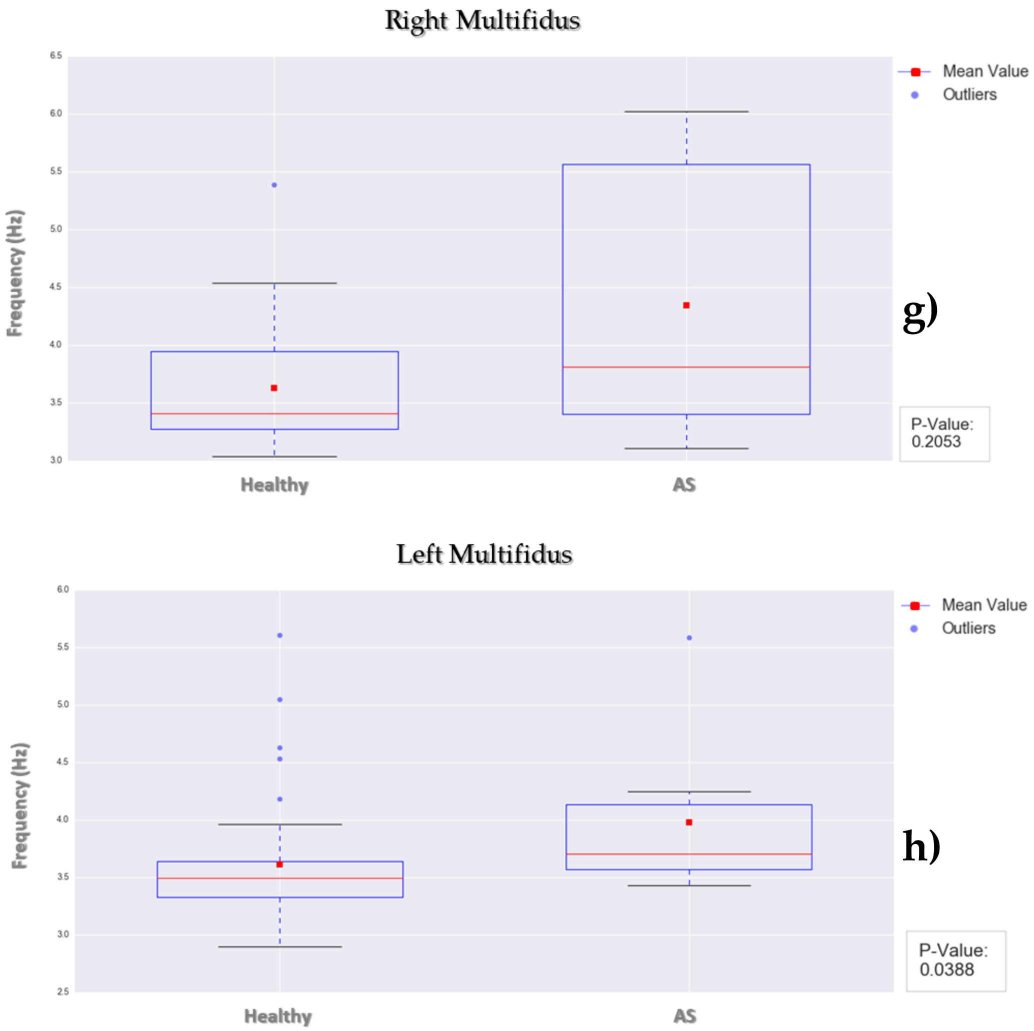
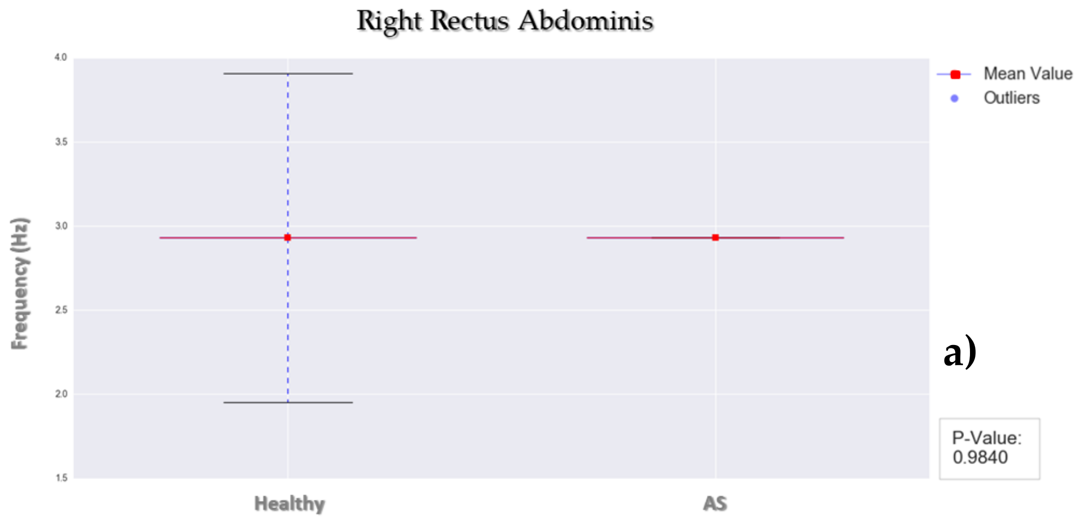
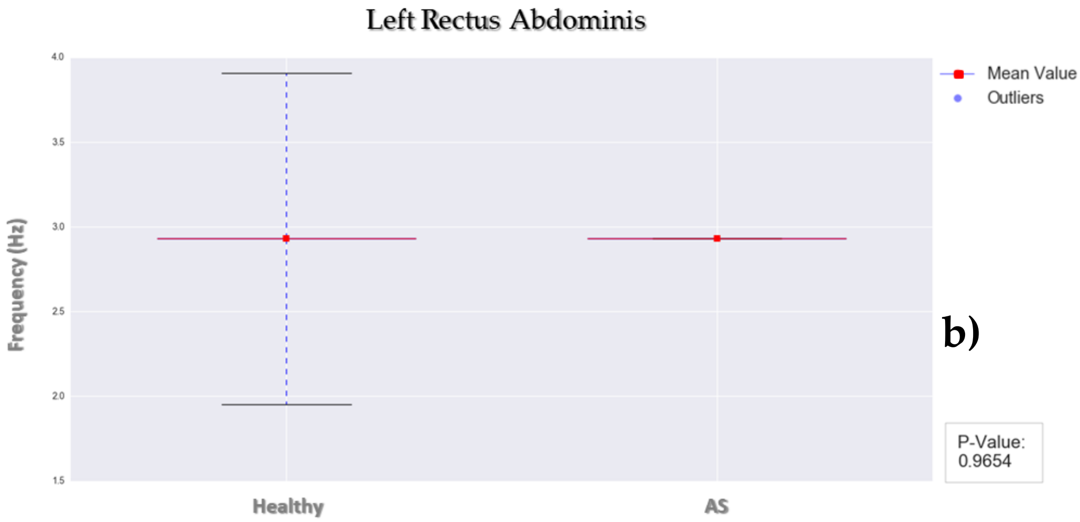
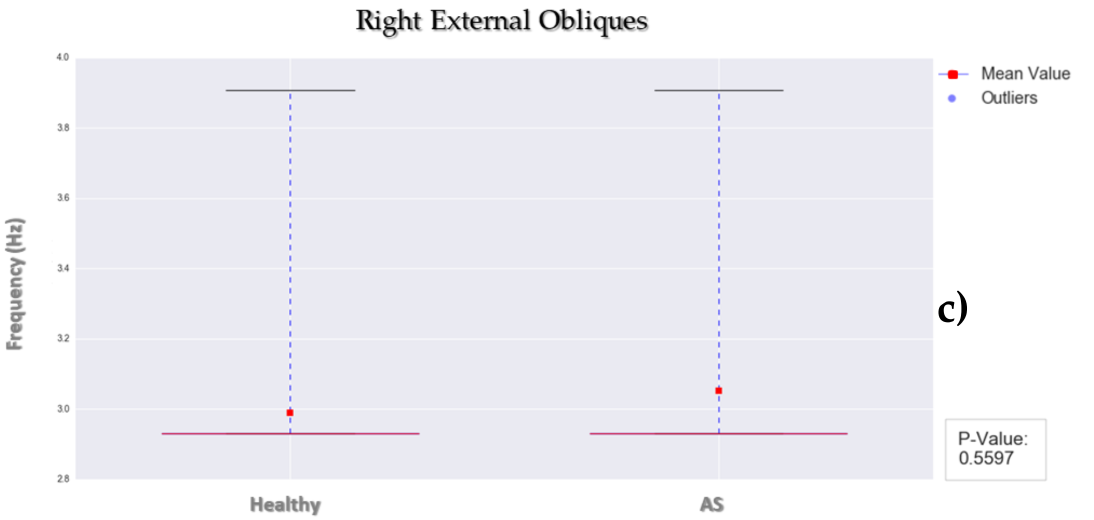


Figure J.3.2 – Mean frequency during rest for each muscle in evaluation. a) Right Rectus Abdominis; b) Left Rectus Abdominis; c) Right External Obliques; d) Left External Obliques; e) Right Iliocostalis; f) Left Iliocostalis; g) Right Multifidus; h) Left Multifidus.

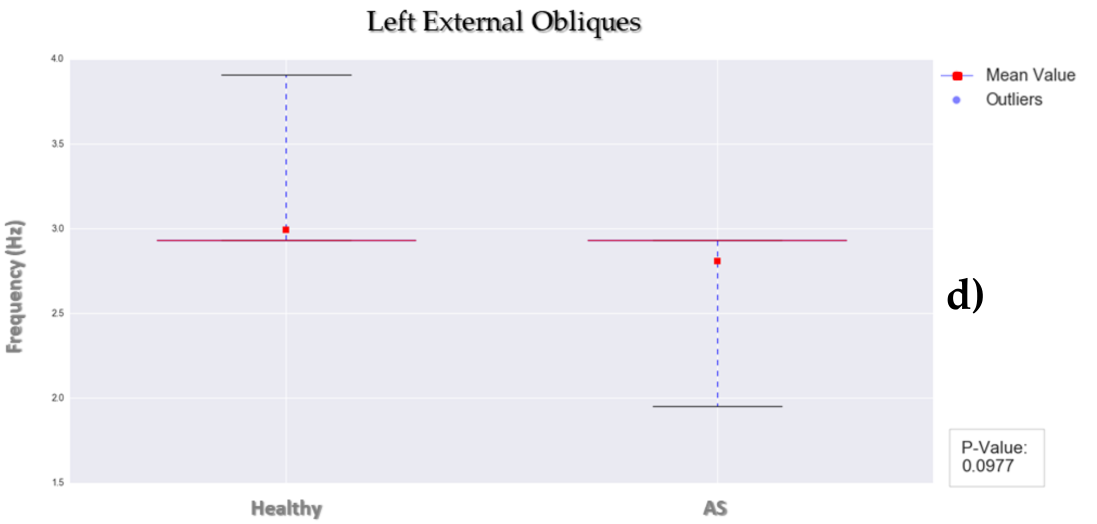
Median Frequency



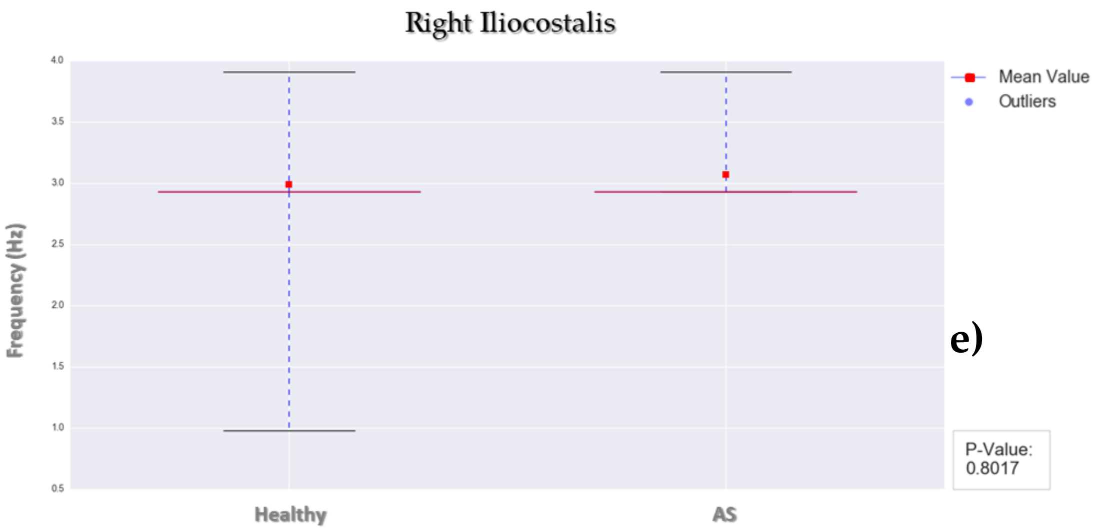



Right External Obliques
Frequency (Hz)
4.0
3.8
3.6
3.4
3.2
3.0
2.8
Healthy
AS
Mean Value
Outliers
P-Value:
0.5597

c)


Left External Obliques
Frequency (Hz)
4.0
3.5
3.0
2.5
2.0
1.5
Healthy
AS
Mean Value
Outliers
P-Value:
0.0977

d)


Right Iliocostalis
Frequency (Hz)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Healthy
AS
Mean Value
Outliers
P-Value:
0.8017

e)

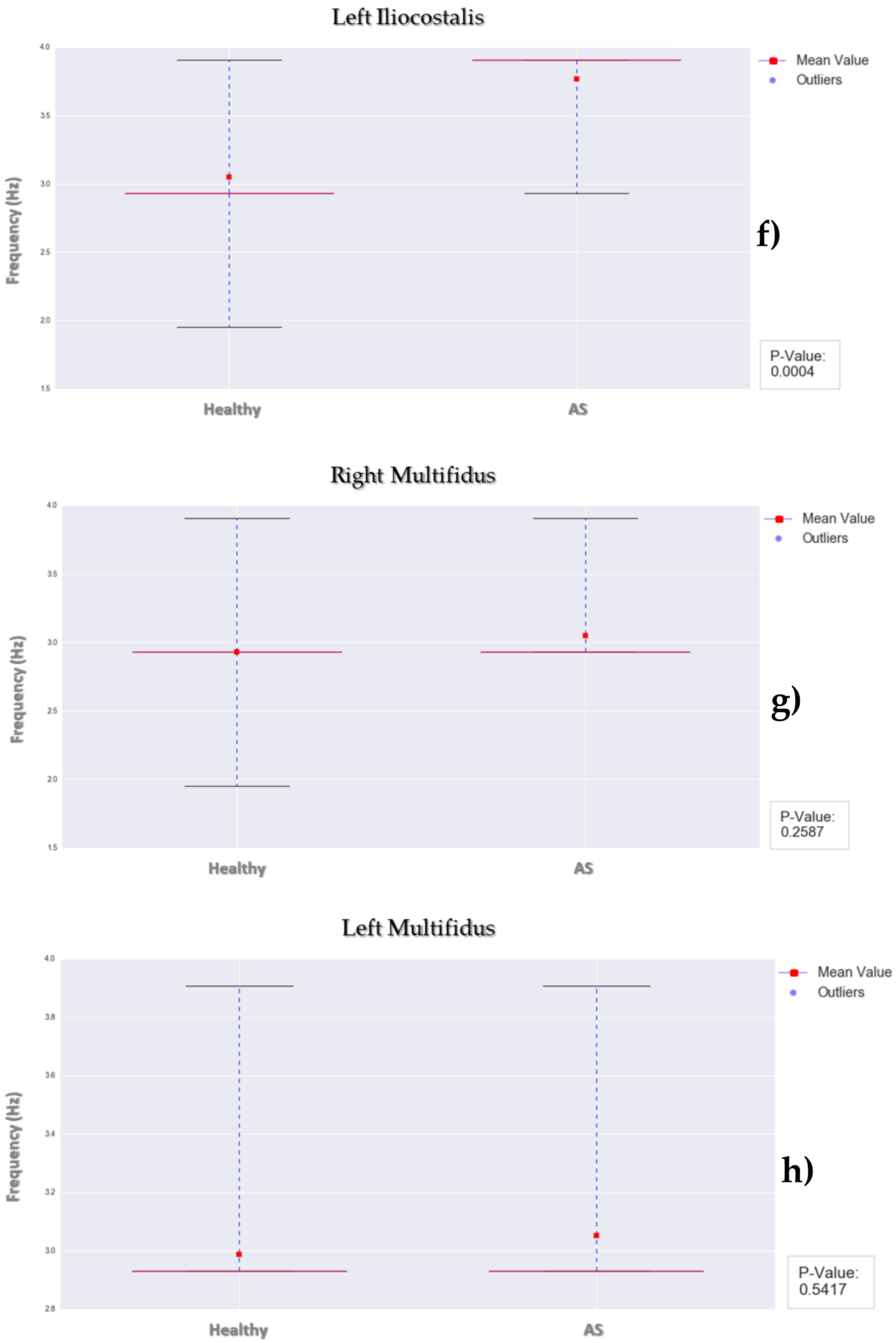
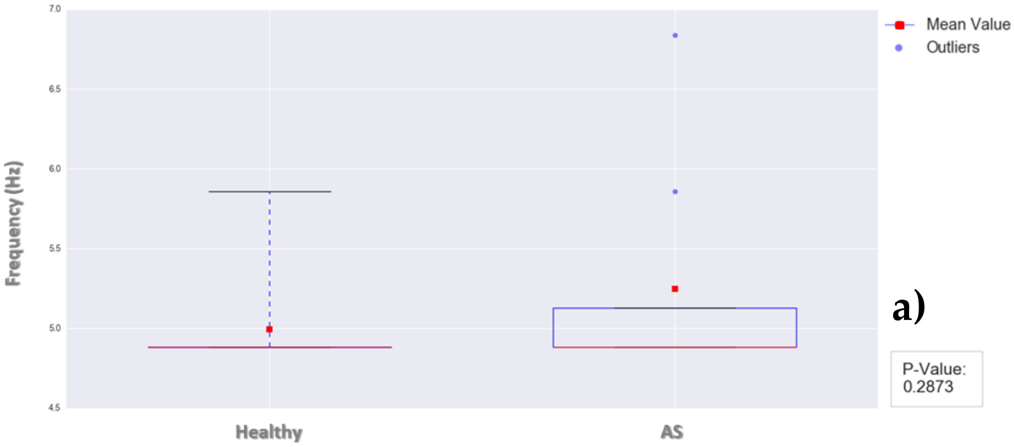


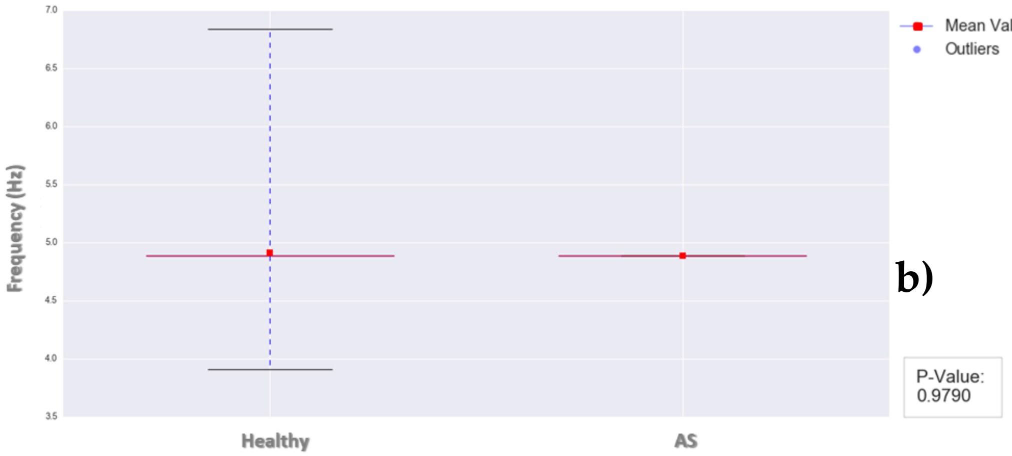
Figure J.3.3 – Median frequency during rest for each muscle in evaluation. a) Right Rectus Abdominis; b) Left Rectus Abdominis; c) Right External Obliques; d) Left External Obliques; e) Right Iliocostalis; f) Left Iliocostalis; g) Right Multifidus; h) Left Multifidus.

Frequency at 80% of power spectrum

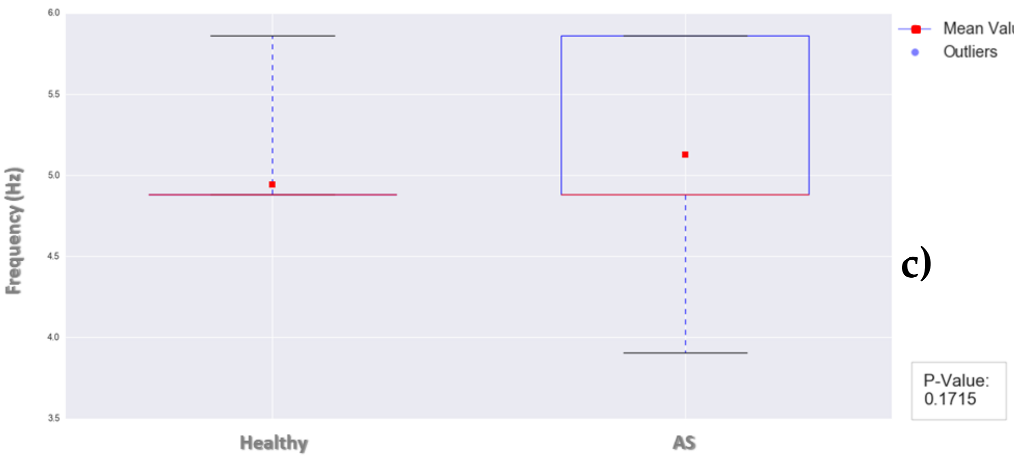
Right Rectus Abdominis

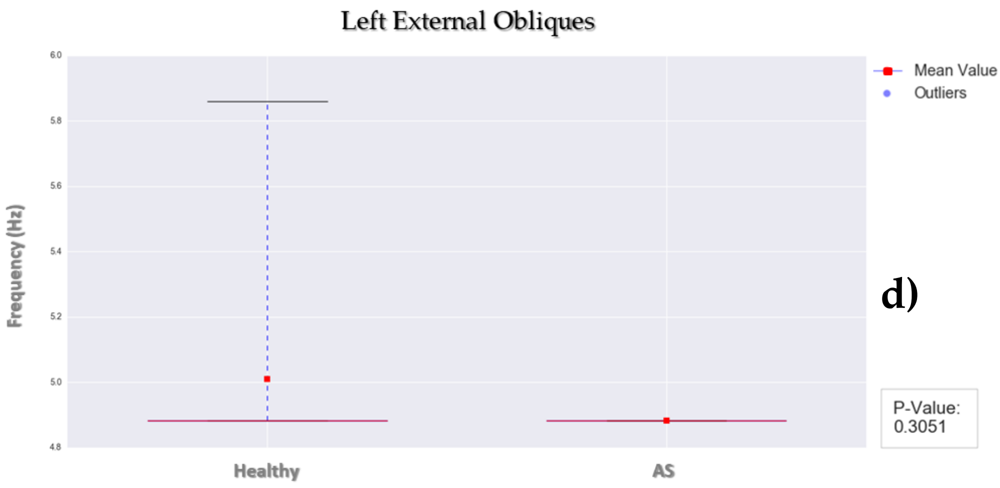


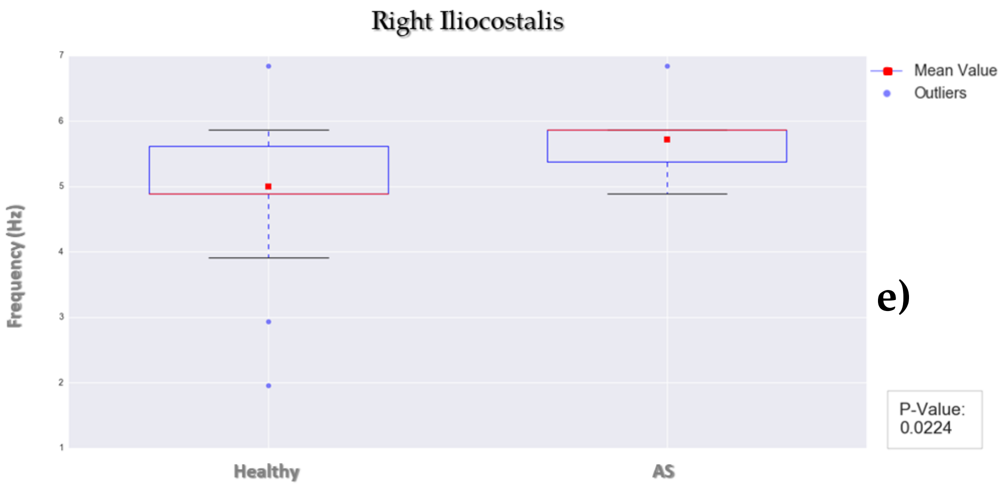
Left Rectus Abdominis

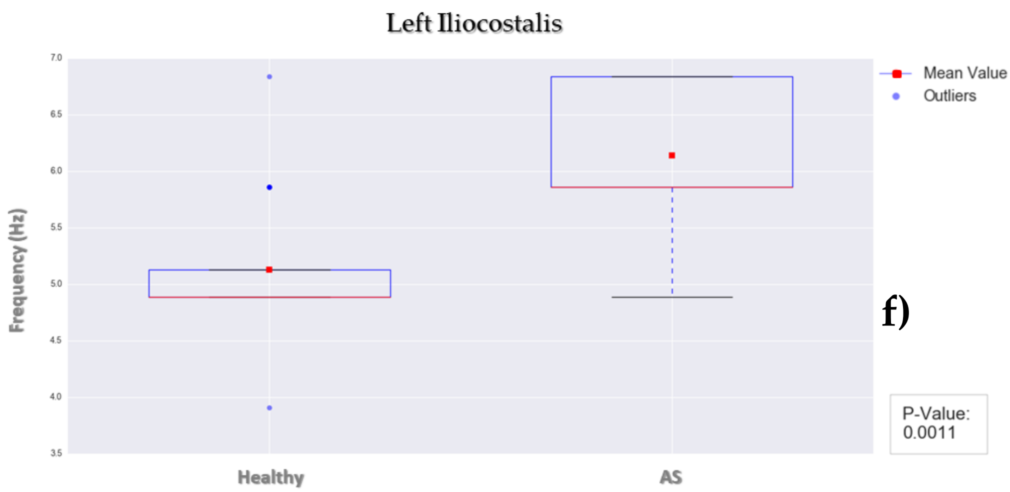


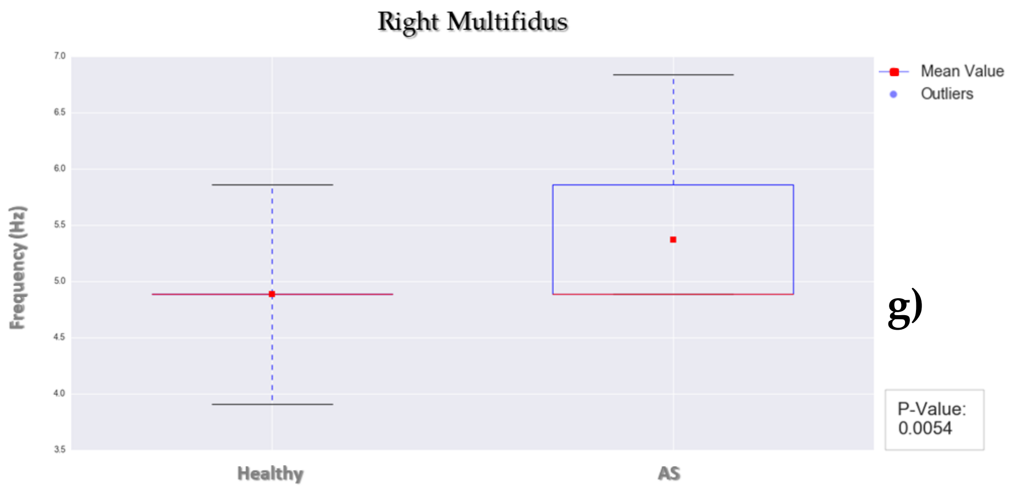
Right External Obliques




Left External Obliques
Frequency (Hz)
6.0
5.8
5.6
5.4
5.2
5.0
4.8
Healthy
AS
Mean Value
Outliers
d)
P-Value:
0.3051


Right Iliocostalis
Frequency (Hz)
7
6
5
4
3
2
1
Healthy
AS
Mean Value
Outliers
e)
P-Value:
0.0224


Left Iliocostalis
Frequency (Hz)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
Healthy
AS
Mean Value
Outliers
f)
P-Value:
0.0011



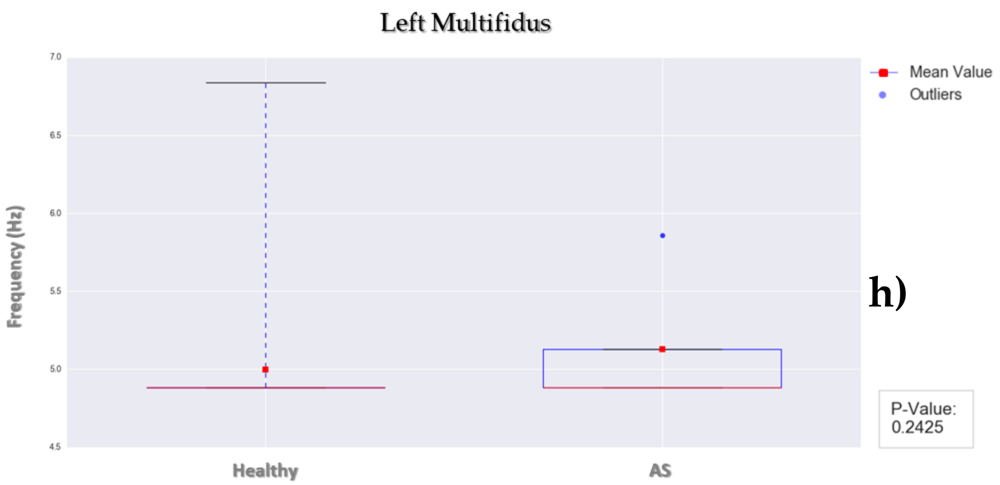
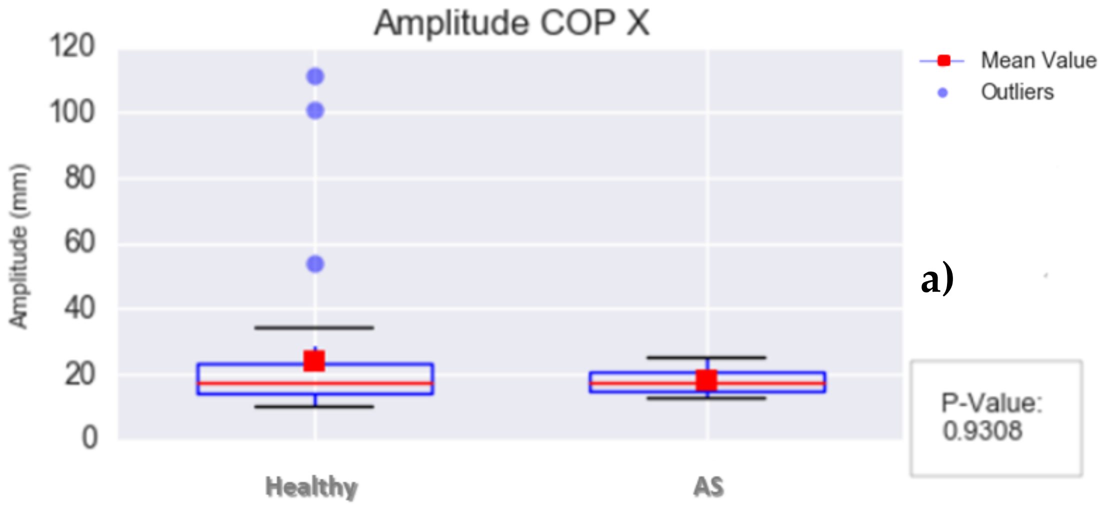
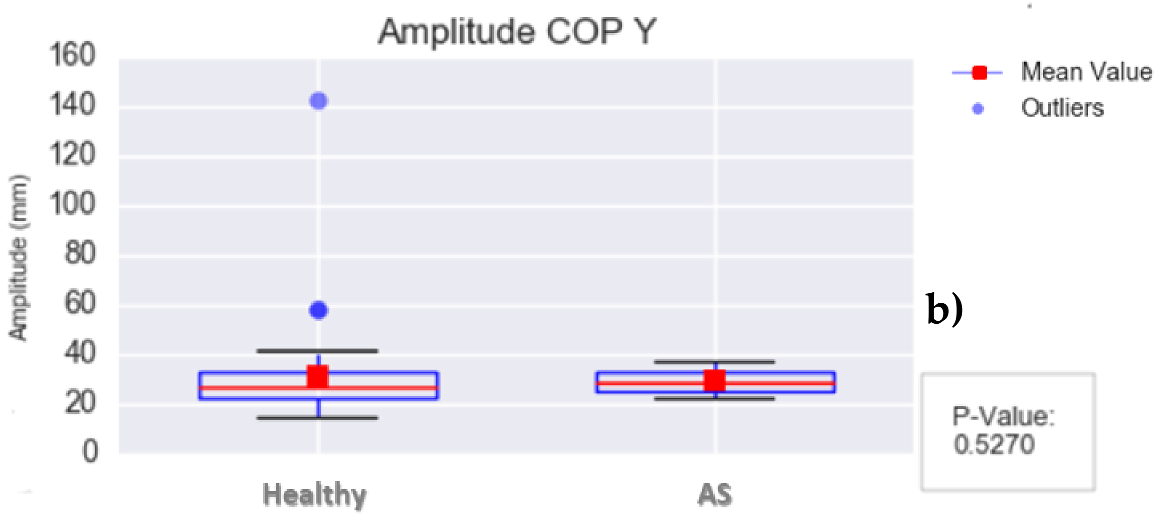


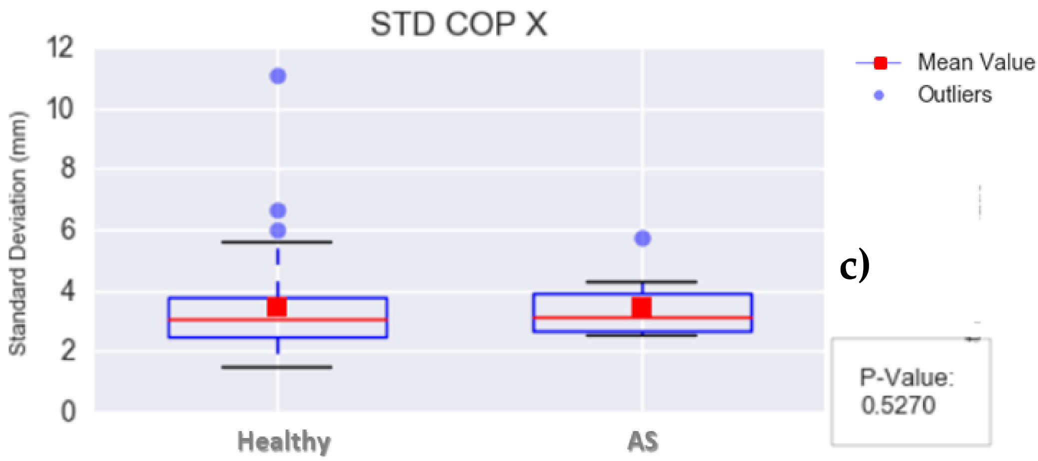
Figure J.3.4 – Frequency at 80% of power spectrum during rest for each muscle in evaluation. a) Right Rectus Abdominis; b) Left Rectus Abdominis; c) Right External Obliques; d) Left External Obliques; e) Right Iliocostalis; f) Left Iliocostalis; g) Right Multifidus; h) Left Multifidus.

J.4 – COP Parameters

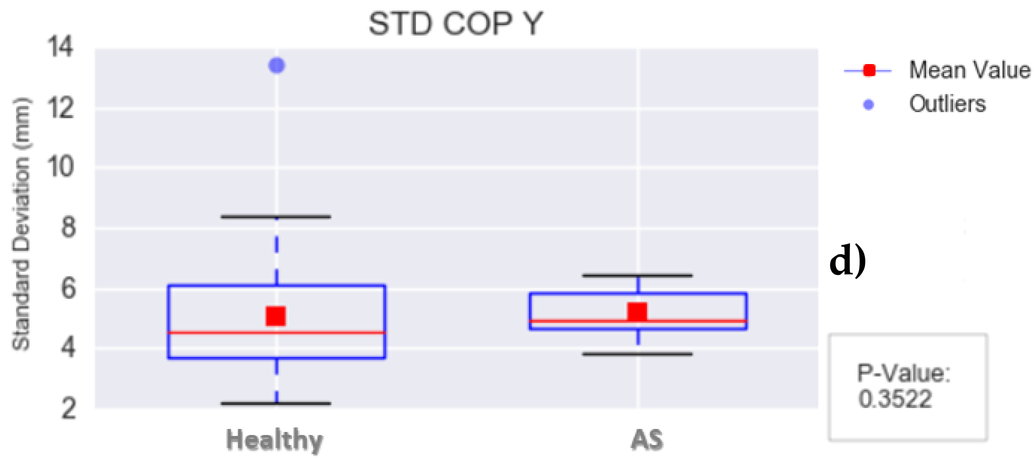
SEO



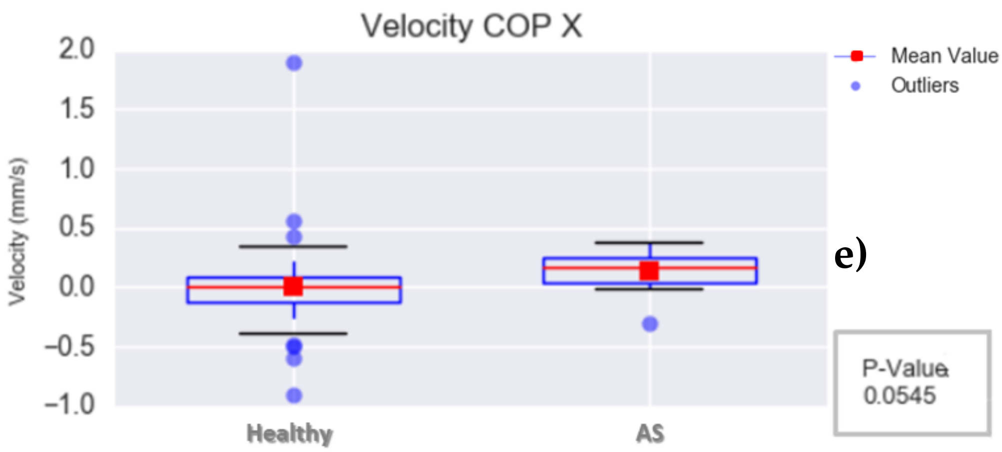



STD COP X
Standard Deviation (mm)
0
2
4
6
8
10
12
Healthy
AS
Mean Value
Outliers
P-Value:
0.5270

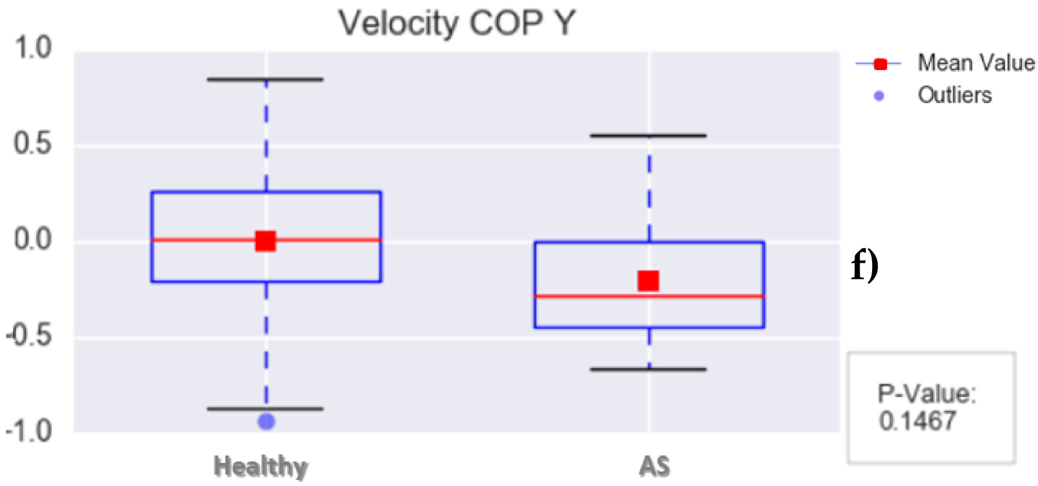
c)


STD COP Y
Standard Deviation (mm)
2
4
6
8
10
12
14
Healthy
AS
Mean Value
Outliers
P-Value:
0.3522

d)


Velocity COP X
Velocity (mm/s)
−1.0
−0.5
0.0
0.5
1.0
1.5
2.0
Healthy
AS
Mean Value
Outliers
P-Value
0.0545

e)



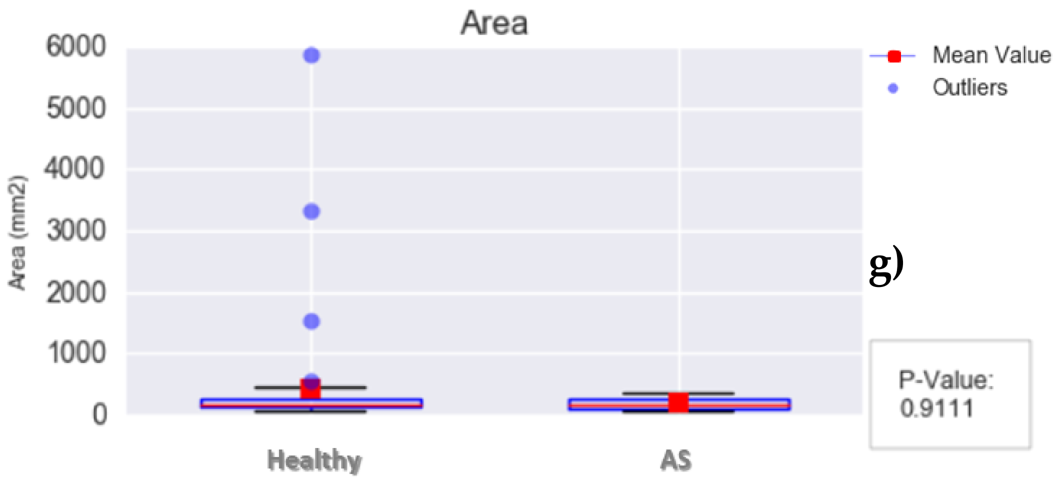
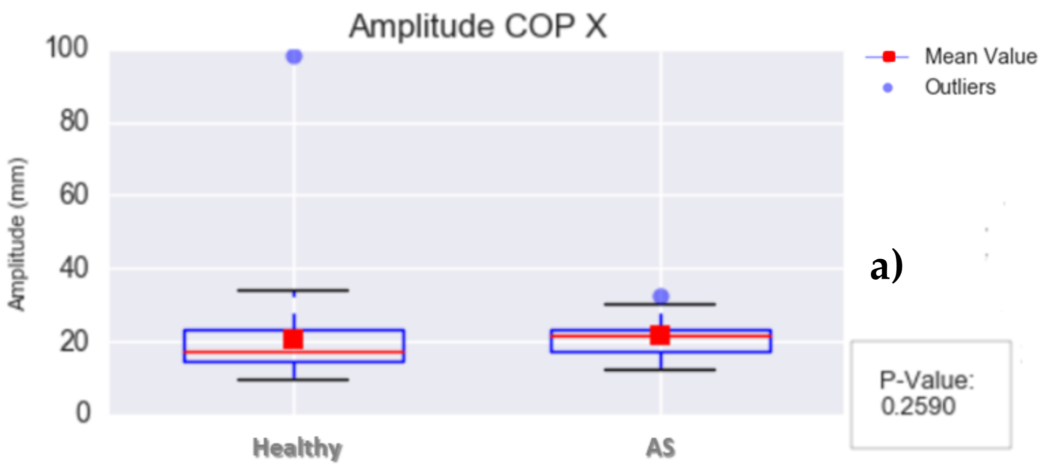
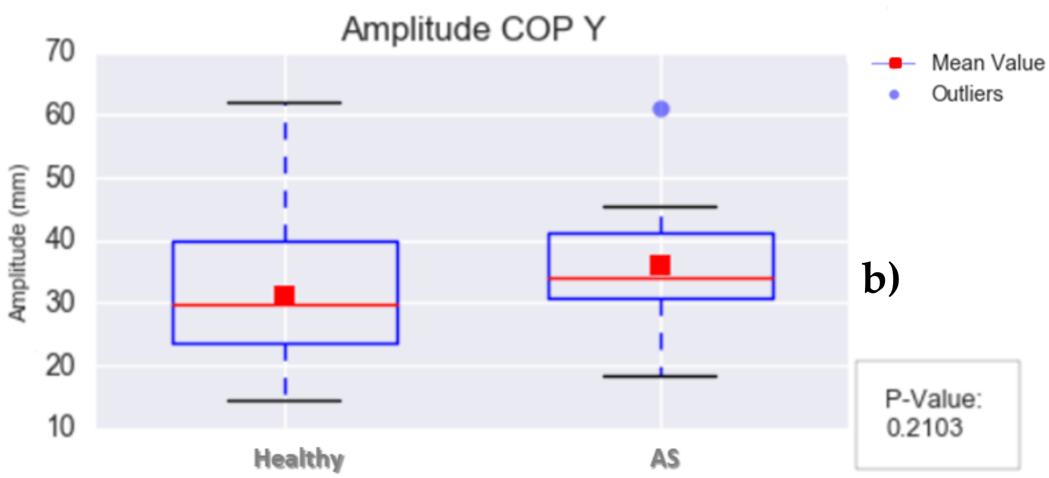
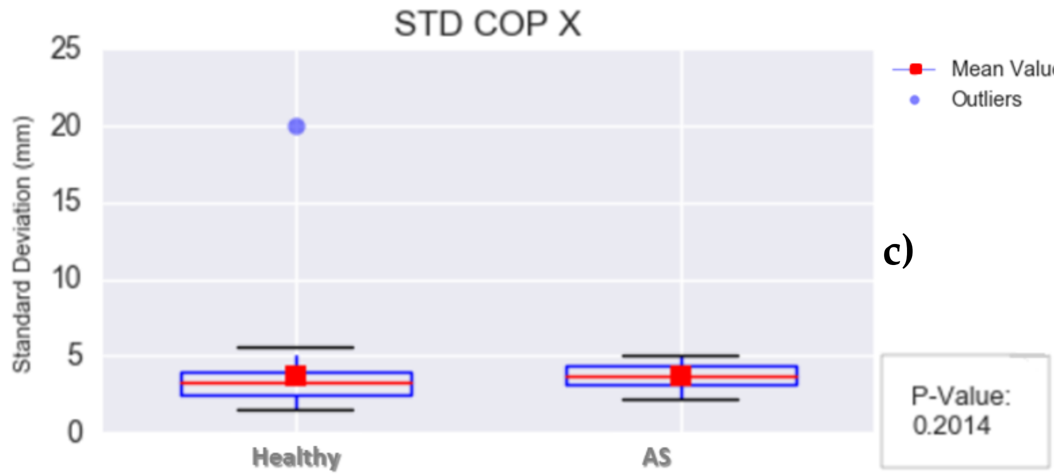


Figure J.4.1 – COP parameters evaluation during SEO (Standing Eyes Open) task. a) COP's amplitude in X direction; b) COP's amplitude in Y direction; c) COP's standard deviation in X direction; d) COP's standard deviation in Y direction; e) Mean Velocity of COP displacement in X direction; f) Mean Velocity of COP displacement in Y direction; g) Area of COP displacement.

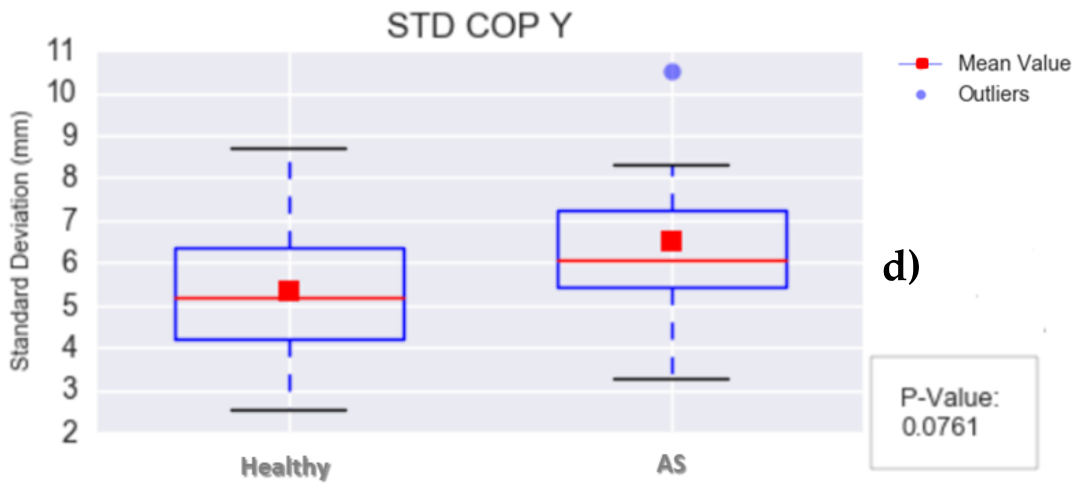
SEC


Amplitude COP X
Amplitude (mm)
100
80
60
40
20
0
Healthy
AS
Mean Value
Outliers
a)
P-Value:
0.2590

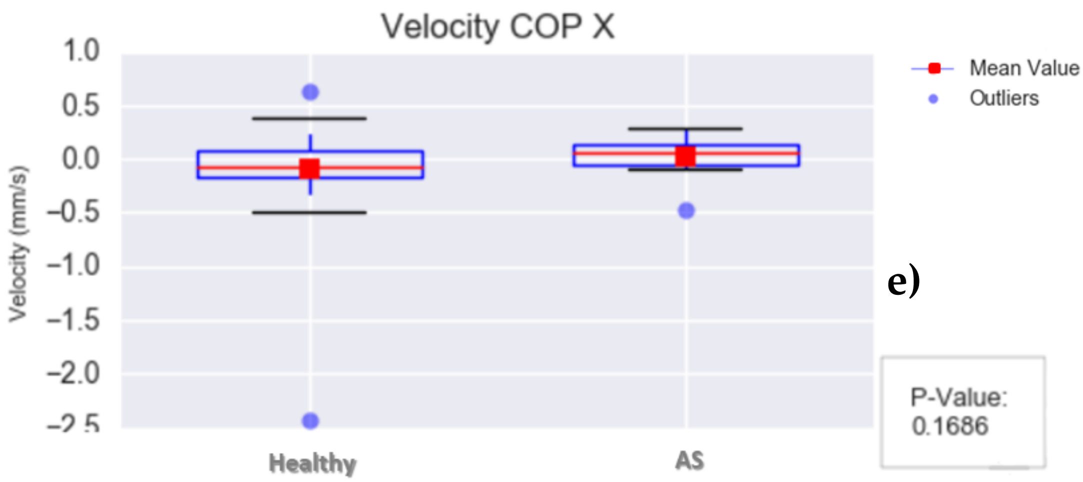

Amplitude COP Y
Amplitude (mm)
70
60
50
40
30
20
10
Healthy
AS
Mean Value
Outliers
b)
P-Value:
0.2103


STD COP X
Standard Deviation (mm)
25
20
15
10
5
0
Healthy
AS
Mean Value
Outliers
P-Value:
0.2014

c)


STD COP Y
Standard Deviation (mm)
11
10
9
8
7
6
5
4
3
2
Healthy
AS
Mean Value
Outliers
P-Value:
0.0761

d)


Velocity COP X
Velocity (mm/s)
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
Healthy
AS
Mean Value
Outliers
P-Value:
0.1686

e)

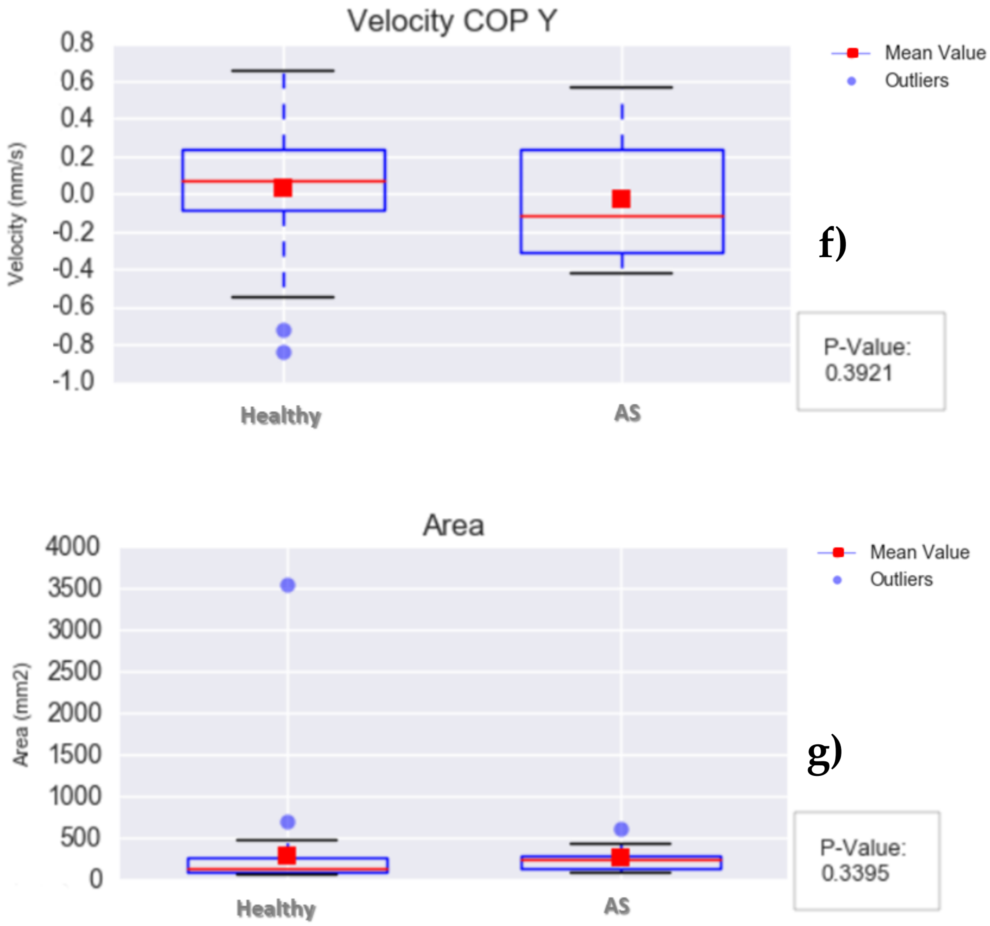
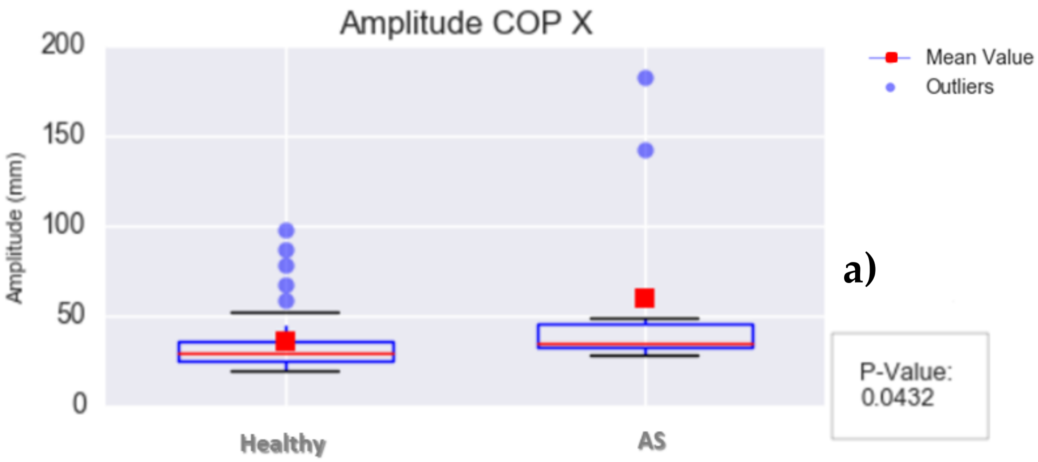
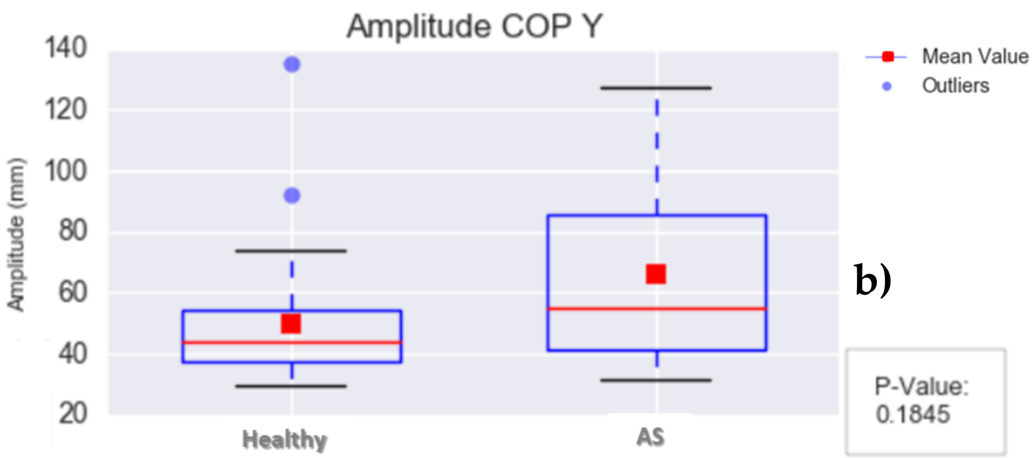
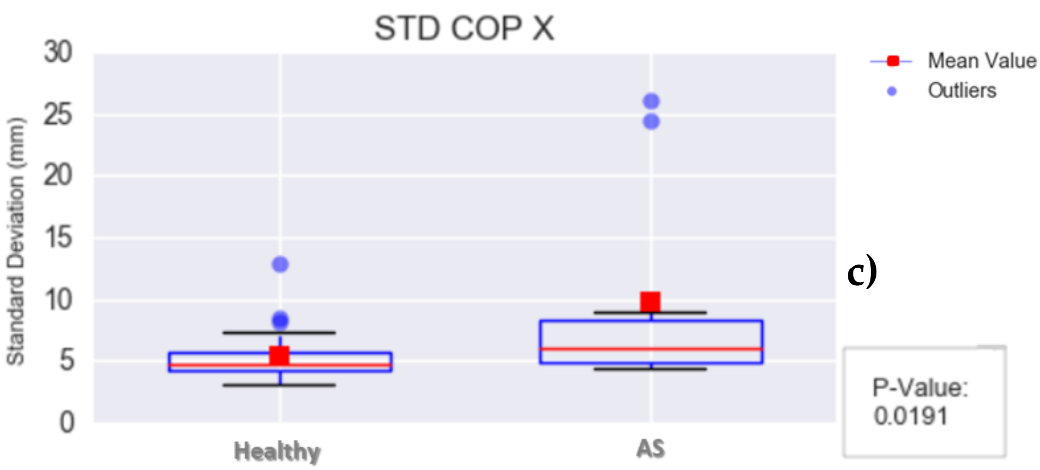
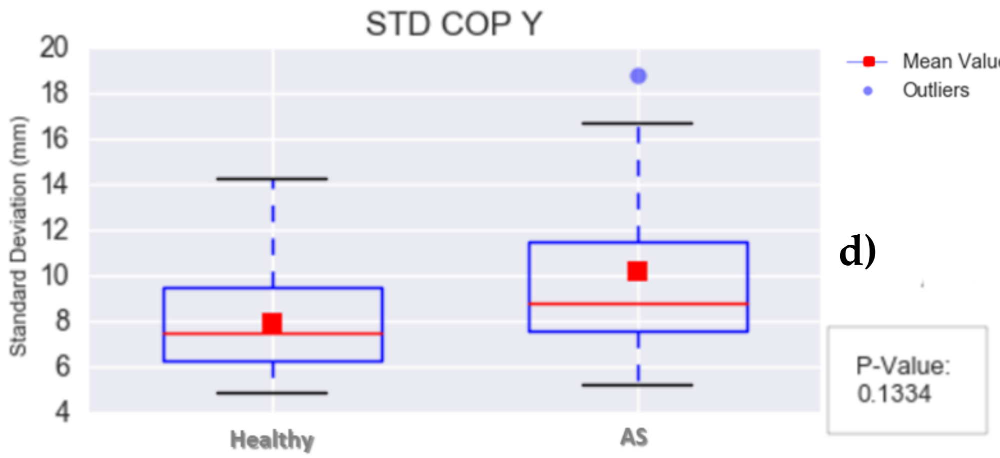


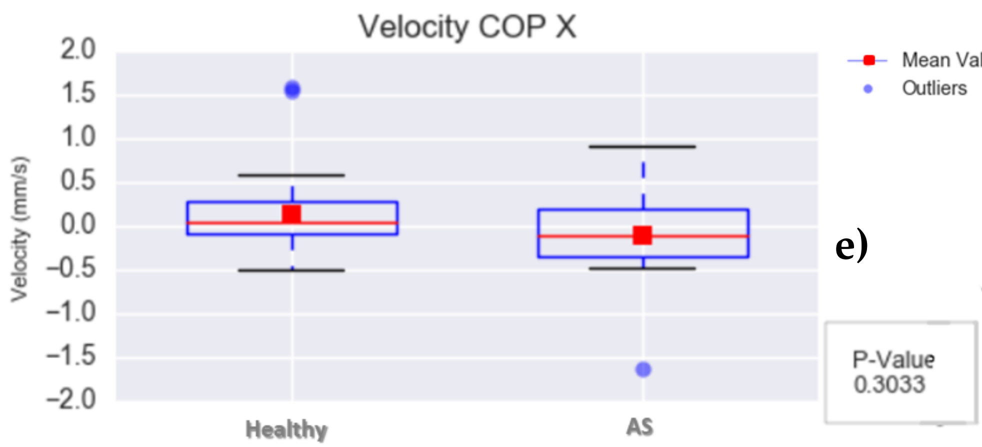
Figure J.4.2 – COP parameters evaluation during SEC (Standing Eyes Close) task. a) COP's amplitude in X direction; b) COP's amplitude in Y direction; c) COP's standard deviation in X direction; d) COP's standard deviation in Y direction; e) Mean Velocity of COP displacement in X direction; f) Mean Velocity of COP displacement in Y direction; g) Area of COP displacement.

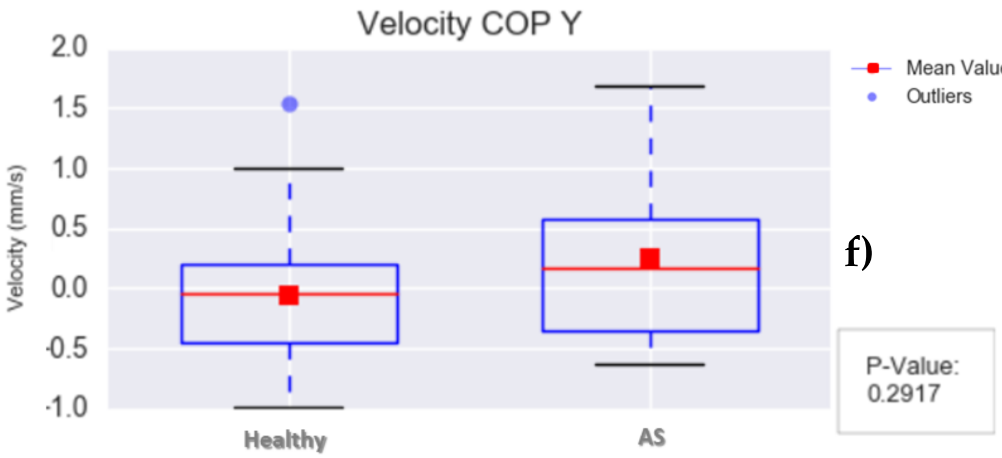

Amplitude COP X
200
150
100
50
0
Amplitude (mm)
Healthy
AS
Mean Value
Outliers
a)
P-Value:
0.0432


Amplitude COP Y
140
120
100
80
60
40
20
Amplitude (mm)
Healthy
AS
Mean Value
Outliers
b)
P-Value:
0.1845


STD COP X
30
25
20
15
10
5
0
Standard Deviation (mm)
Healthy
AS
Mean Value
Outliers
c)
P-Value:
0.0191


STD COP Y
Standard Deviation (mm)
20
18
16
14
12
10
8
6
4
Healthy
AS
Mean Value
Outliers
d)
P-Value:
0.1334


Velocity COP X
Velocity (mm/s)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
Healthy
AS
Mean Value
Outliers
e)
P-Value
0.3033


Velocity COP Y
Velocity (mm/s)
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
Healthy
AS
Mean Value
Outliers
f)
P-Value:
0.2917

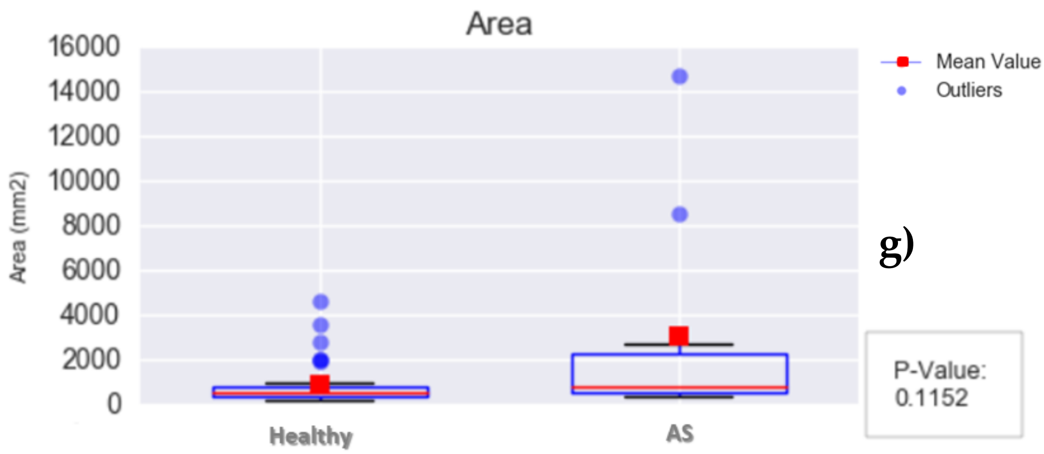
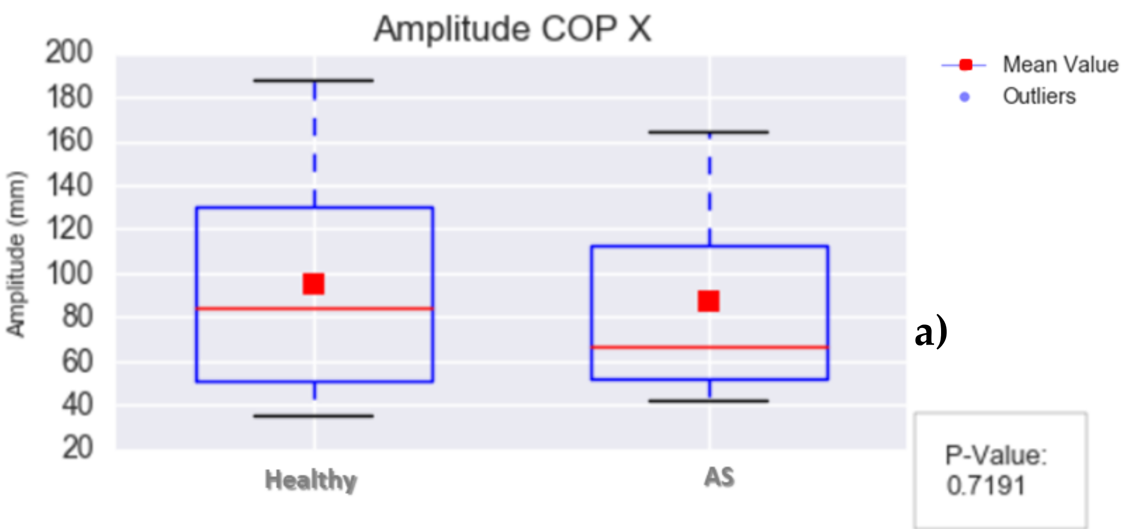
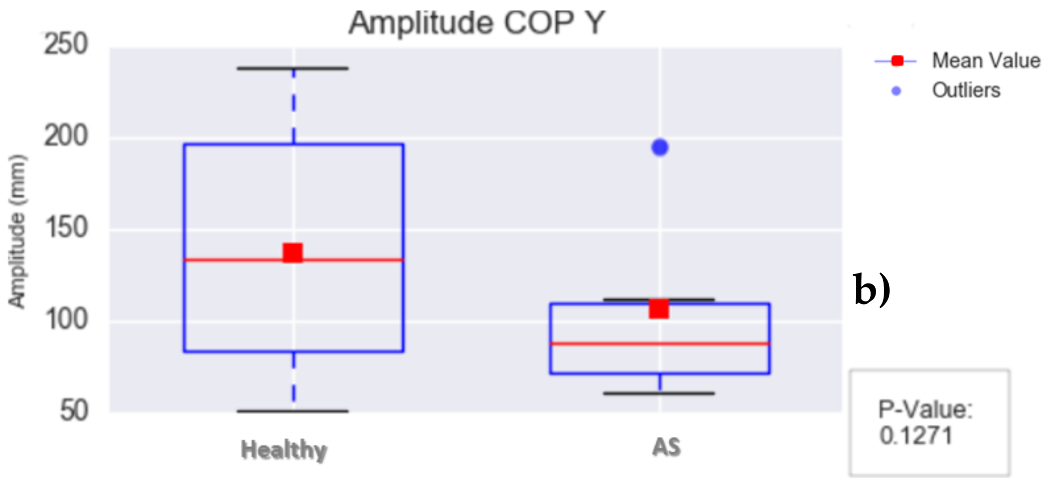


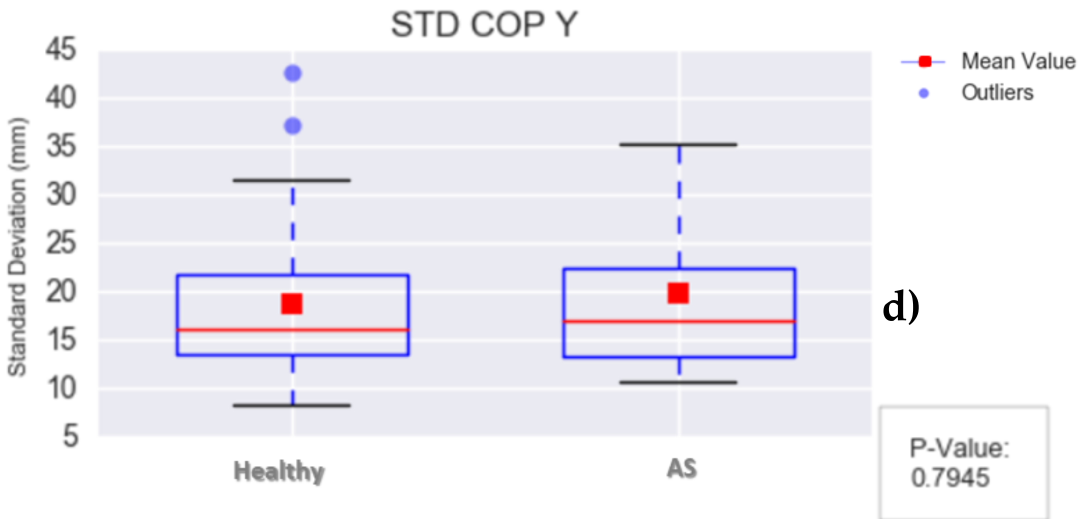
Figure J.4.3 – COP parameters evaluation during RFEO (Right Foot Standing Eyes Open) task. a) COP's amplitude in X direction; b) COP's amplitude in Y direction; c) COP's standard deviation in X direction; d) COP's standard deviation in Y direction; e) Mean Velocity of COP displacement in X direction; f) Mean Velocity of COP displacement in Y direction; g) Area of COP displacement.

RFEC




Amplitude COP Y
Amplitude (mm)
250
200
150
100
50
Healthy
AS
Mean Value
Outliers
b)
P-Value:
0.1271


STD COP X
Standard Deviation (mm)
40
35
30
25
20
15
10
5
Healthy
AS
Mean Value
Outliers
c)
P-Value:
0.4346


STD COP Y
Standard Deviation (mm)
45
40
35
30
25
20
15
10
5
Healthy
AS
Mean Value
Outliers
d)
P-Value:
0.7945

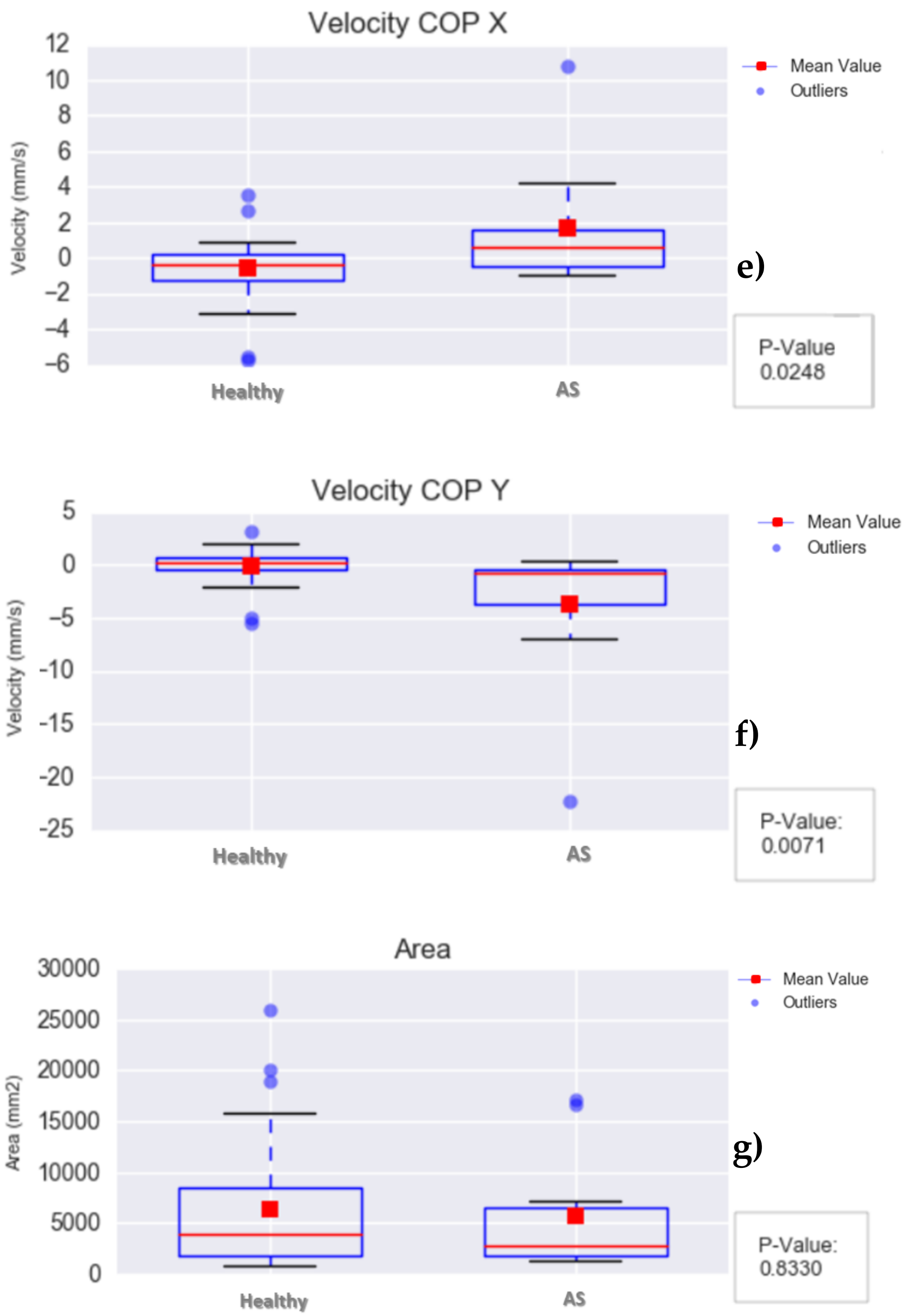
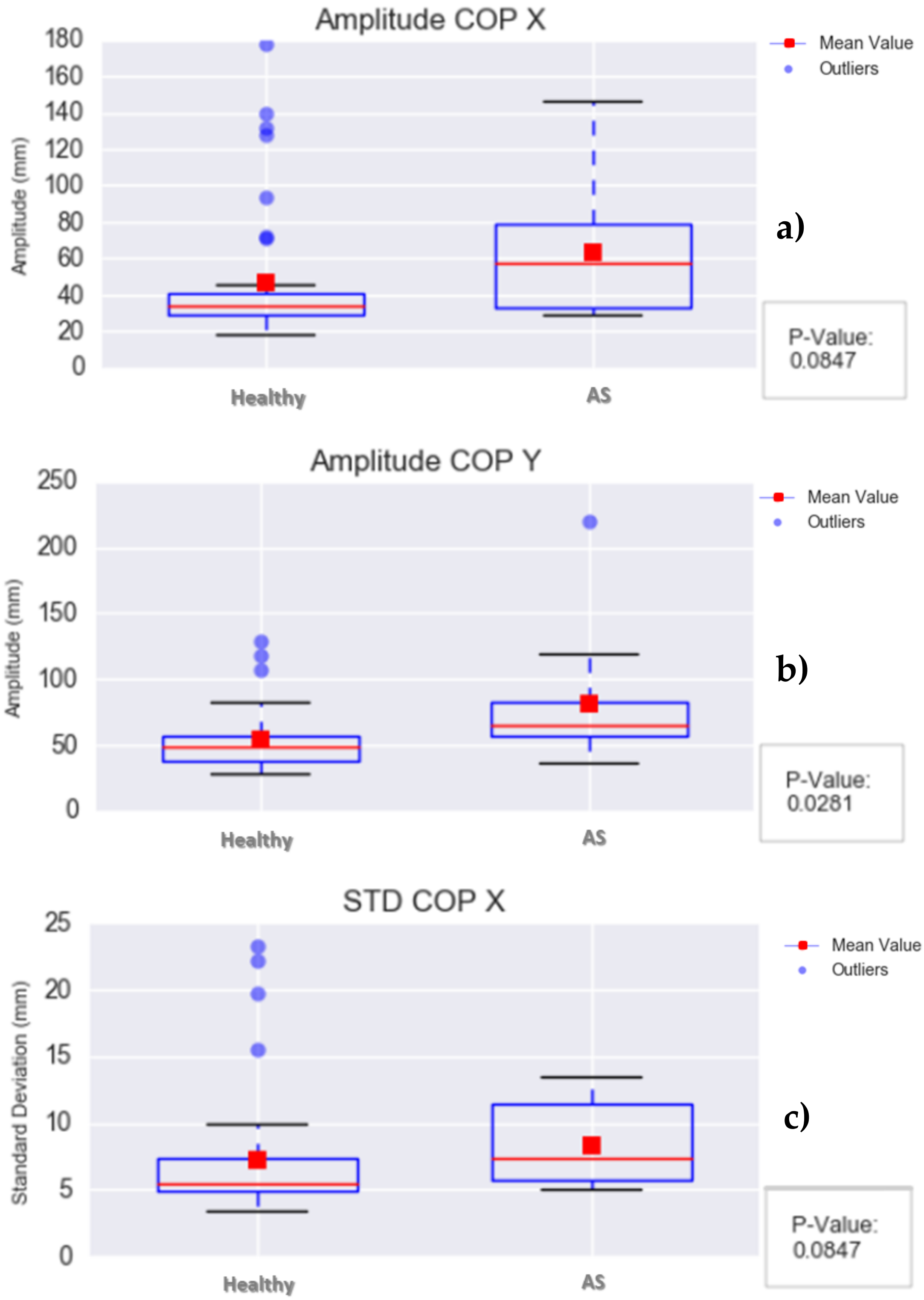
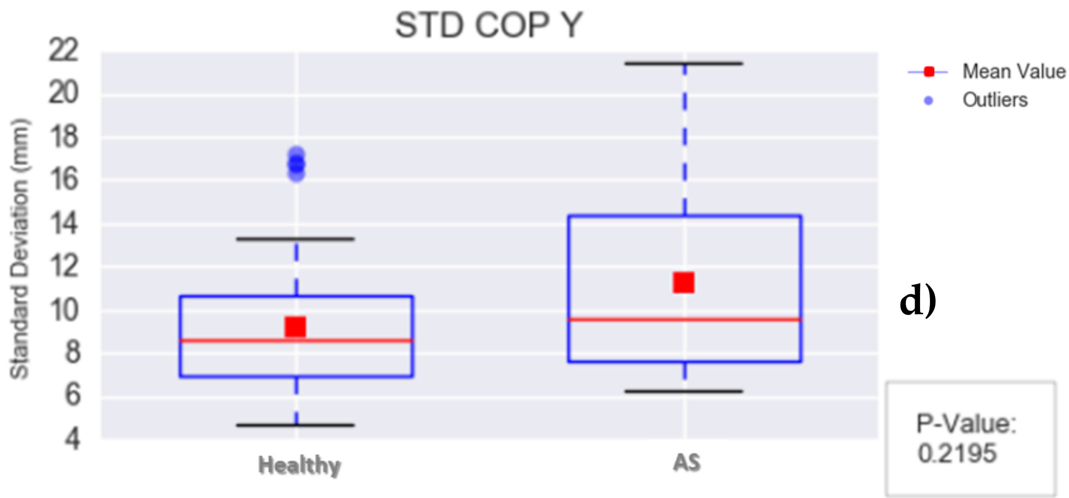
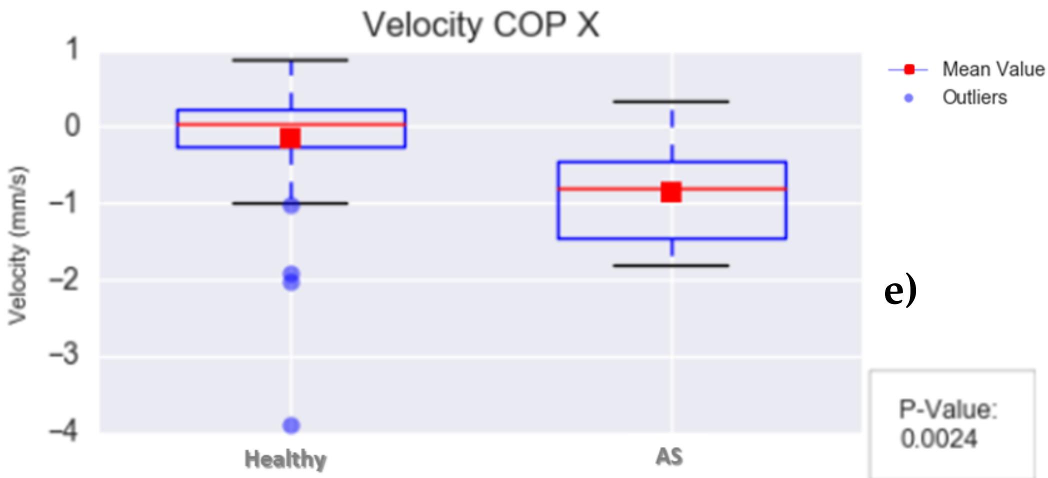


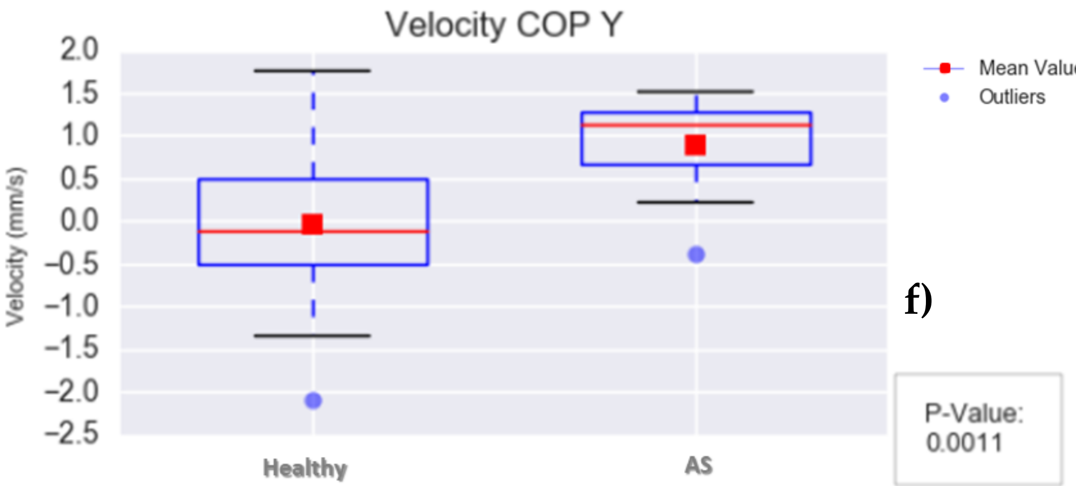
Figure J.4.4 – COP parameters evaluation during RFEC (Right Foot Standing Eyes Close) task. a) COP's amplitude in X direction; b) COP's amplitude in Y direction; c) COP's standard deviation in X direction; d) COP's standard deviation in Y direction; e) Mean Velocity of COP displacement in X direction; f) Mean Velocity of COP displacement in Y direction; g) Area of COP displacement.

LFEO


Amplitude COP X
Amplitude (mm)
Mean Value
Outliers
Healthy
AS
a)
P-Value: 0.0847
Amplitude COP Y
Amplitude (mm)
Mean Value
Outliers
Healthy
AS
b)
P-Value: 0.0281
STD COP X
Standard Deviation (mm)
Mean Value
Outliers
Healthy
AS
c)
P-Value: 0.0847


STD COP Y
Standard Deviation (mm)
22
20
18
16
14
12
10
8
6
4
Healthy
AS
Mean Value
Outliers
d)
P-Value:
0.2195


Velocity COP X
Velocity (mm/s)
1
0
−1
−2
−3
−4
Healthy
AS
Mean Value
Outliers
e)
P-Value:
0.0024


Velocity COP Y
Velocity (mm/s)
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
Healthy
AS
Mean Value
Outliers
f)
P-Value:
0.0011

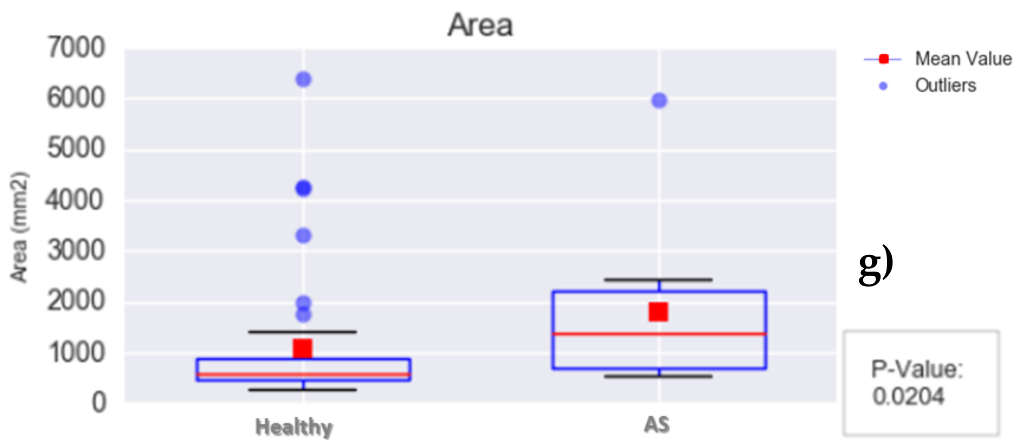
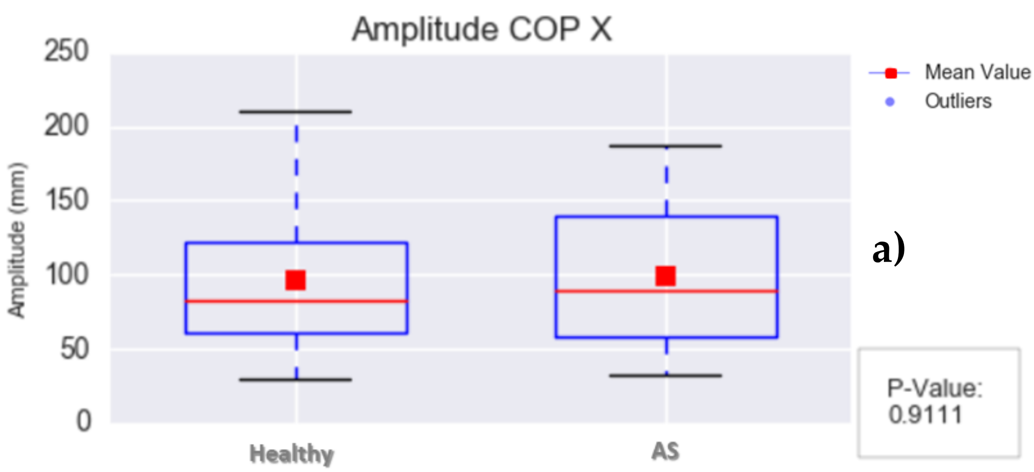
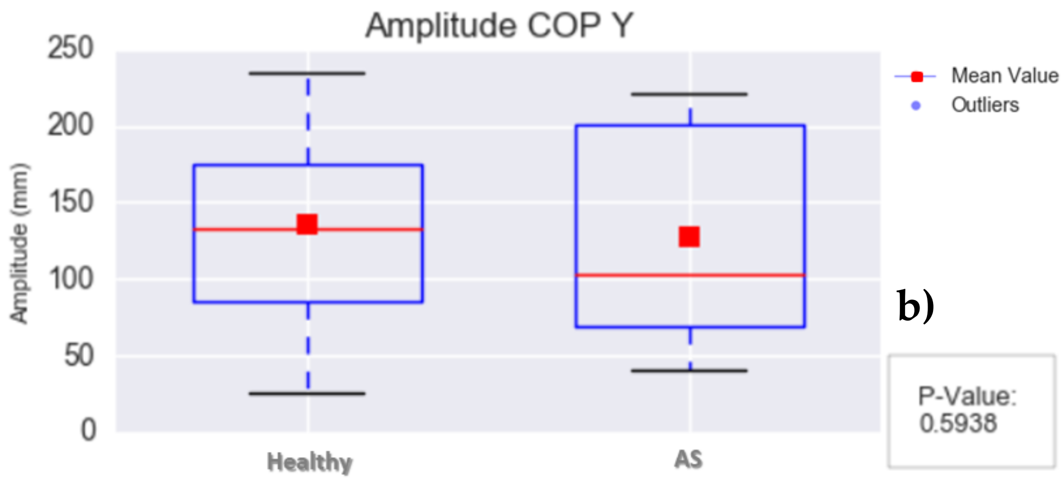
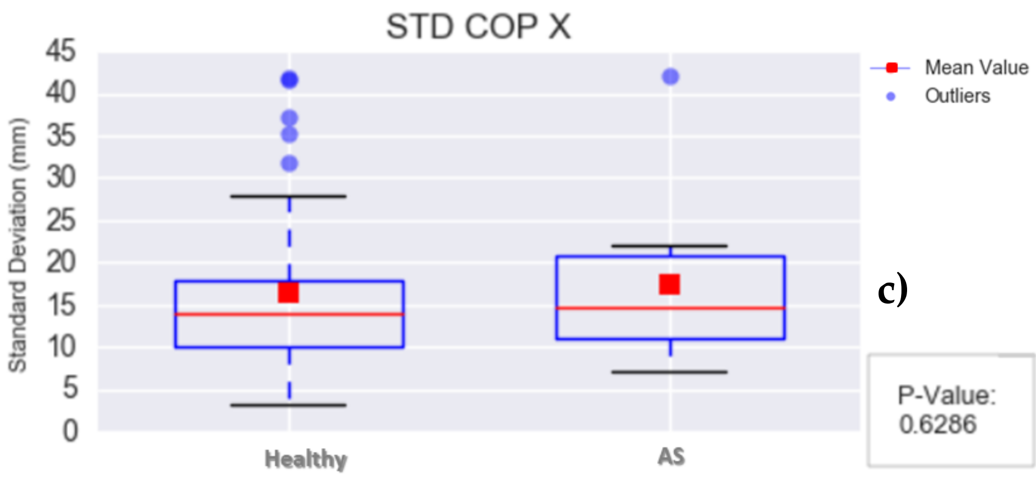


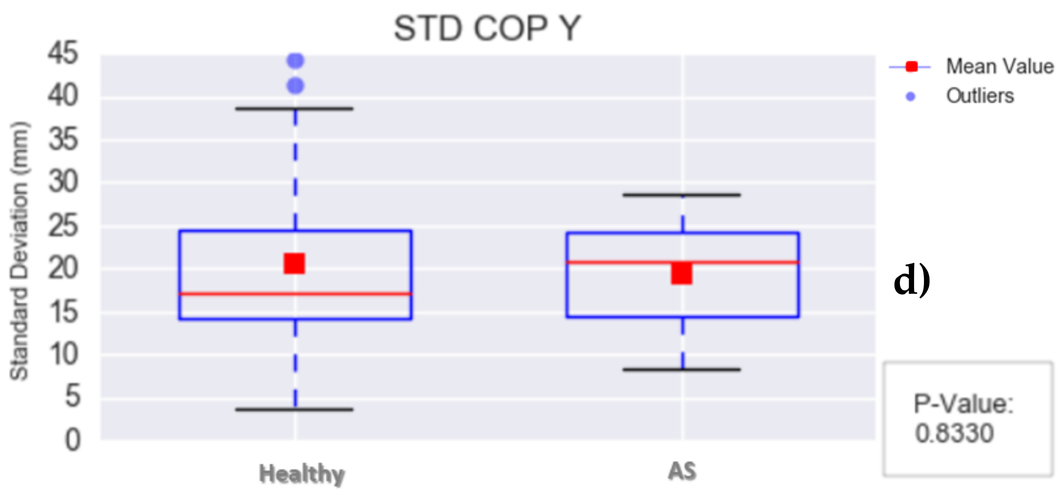
Figure J.4.5 – COP parameters evaluation during LFEO (Left Foot Eyes Open) task. a) COP's amplitude in X direction; b) COP's amplitude in Y direction; c) COP's standard deviation in X direction; d) COP's standard deviation in Y direction; e) Mean Velocity of COP displacement in X direction; f) Mean Velocity of COP displacement in Y direction; g) Area of COP displacement.

LFEC



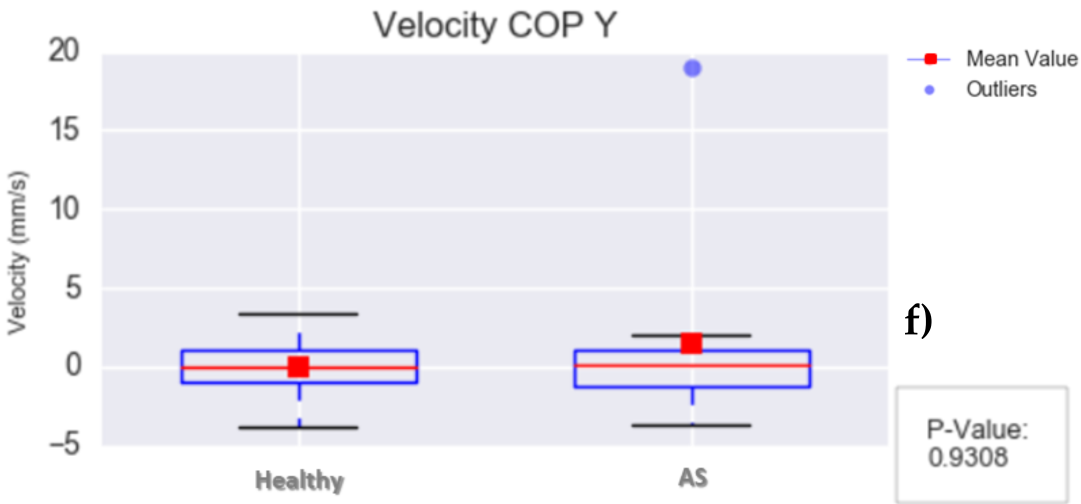

Amplitude COP Y
Amplitude (mm)
250
200
150
100
50
0
Healthy
AS
Mean Value
Outliers
b)
P-Value:
0.5938


STD COP X
Standard Deviation (mm)
45
40
35
30
25
20
15
10
5
0
Healthy
AS
Mean Value
Outliers
c)
P-Value:
0.6286

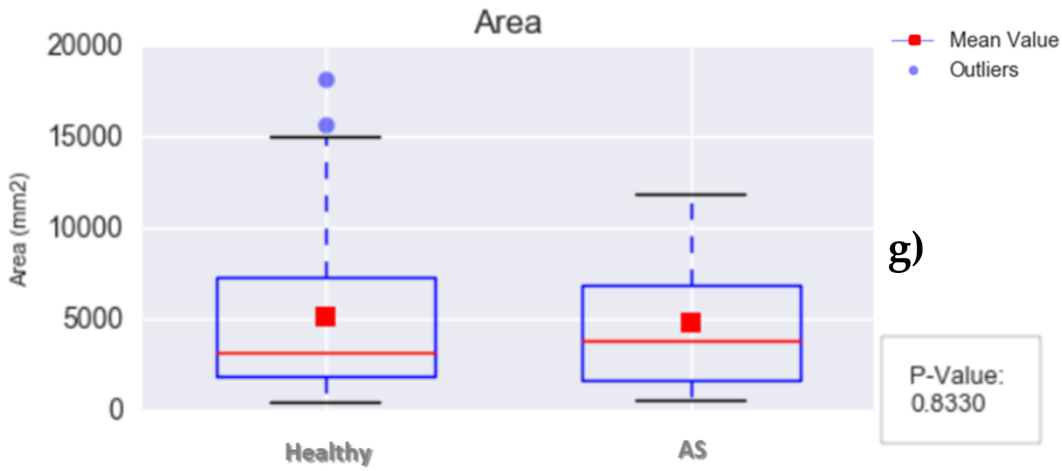

STD COP Y
Standard Deviation (mm)
45
40
35
30
25
20
15
10
5
0
Healthy
AS
Mean Value
Outliers
d)
P-Value:
0.8330


Velocity COP X
Velocity (mm/s)
10
0
−10
−20
−30
−40
Healthy
AS
Mean Value
Outliers
P-Value:
0.5938

e)


Velocity COP Y
Velocity (mm/s)
20
15
10
5
0
−5
Healthy
AS
Mean Value
Outliers
P-Value:
0.9308

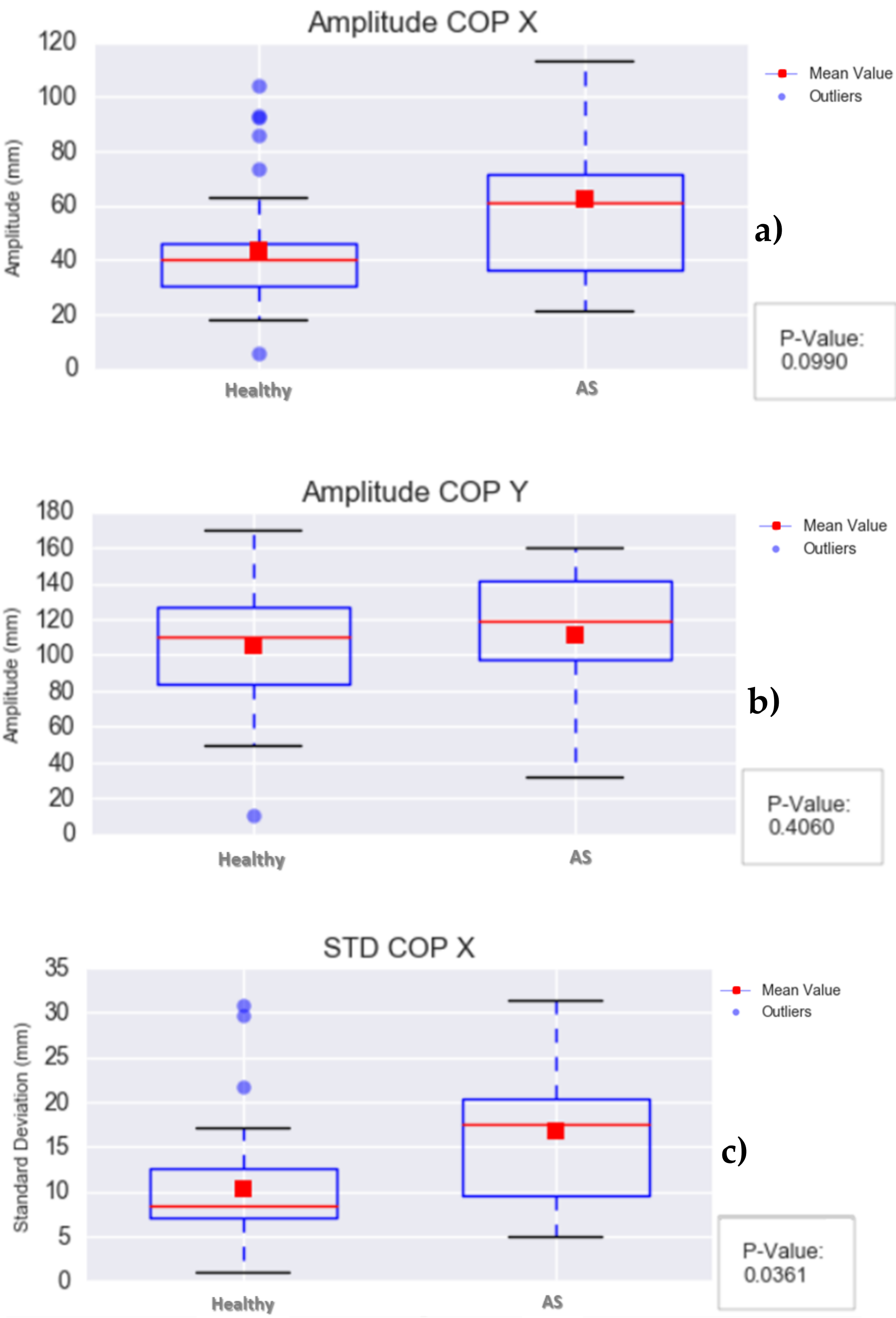
f)

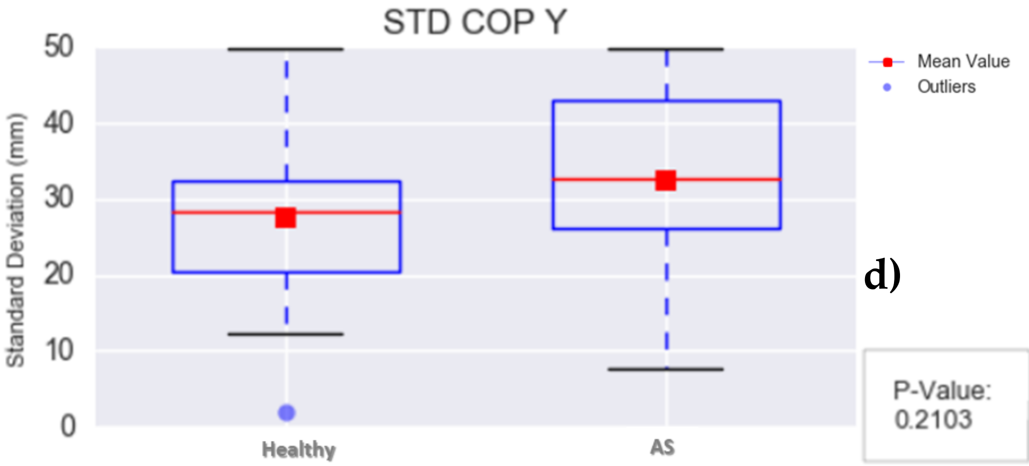


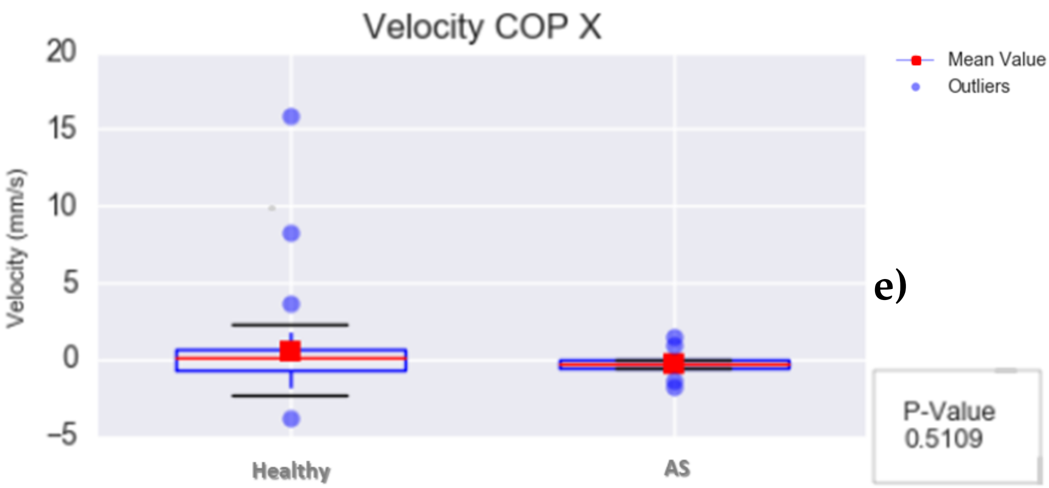
g)

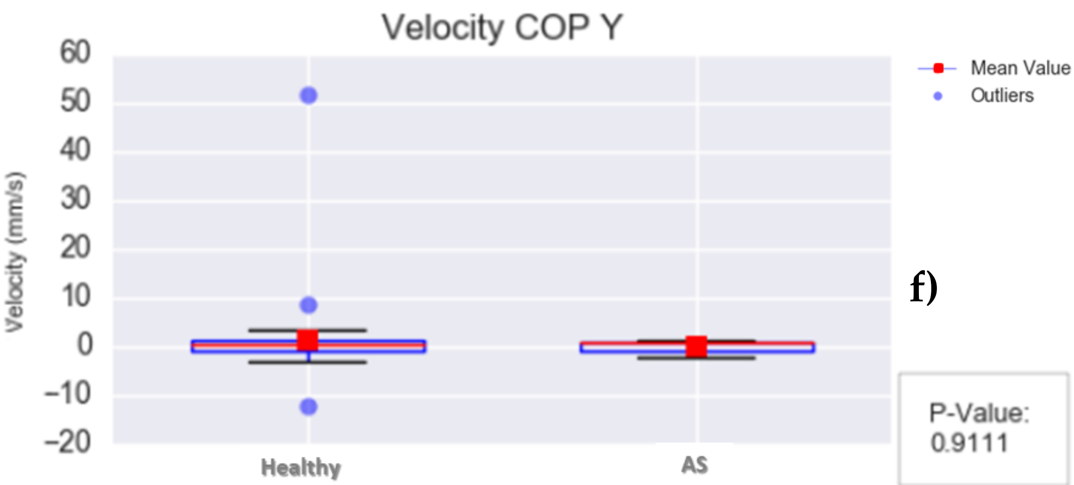
Figure J.4.6 – COP parameters evaluation during LFEC (Left Foot Standing Eyes Close) task. a) COP's amplitude in X direction; b) COP's amplitude in Y direction; c) COP's standard deviation in X direction; d) COP's standard deviation in Y direction; e) Mean Velocity of COP displacement in X direction; f) Mean Velocity of COP displacement in Y direction; g) Area of COP displacement.

RR


Amplitude COP X
Amplitude (mm)
120
100
80
60
40
20
0
Healthy
AS
Mean Value
Outliers
a)
P-Value:
0.0990
Amplitude COP Y
Amplitude (mm)
180
160
140
120
100
80
60
40
20
0
Healthy
AS
Mean Value
Outliers
b)
P-Value:
0.4060
STD COP X
Standard Deviation (mm)
35
30
25
20
15
10
5
0
Healthy
AS
Mean Value
Outliers
c)
P-Value:
0.0361


STD COP Y
Standard Deviation (mm)
50
40
30
20
10
0
Healthy
AS
Mean Value
Outliers
d)
P-Value:
0.2103


Velocity COP X
Velocity (mm/s)
20
15
10
5
0
−5
Healthy
AS
Mean Value
Outliers
e)
P-Value
0.5109


Velocity COP Y
Velocity (mm/s)
60
50
40
30
20
10
0
−10
−20
Healthy
AS
Mean Value
Outliers
f)
P-Value:
0.9111

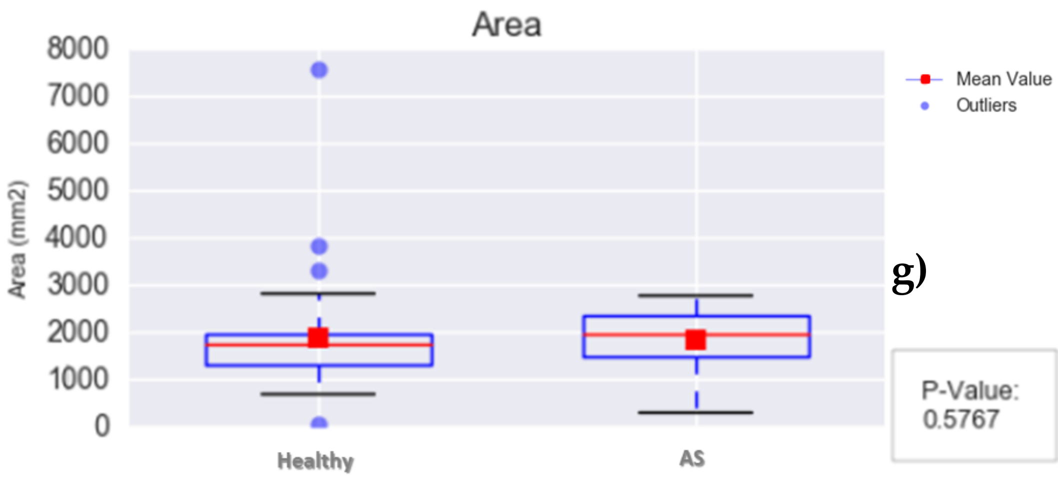
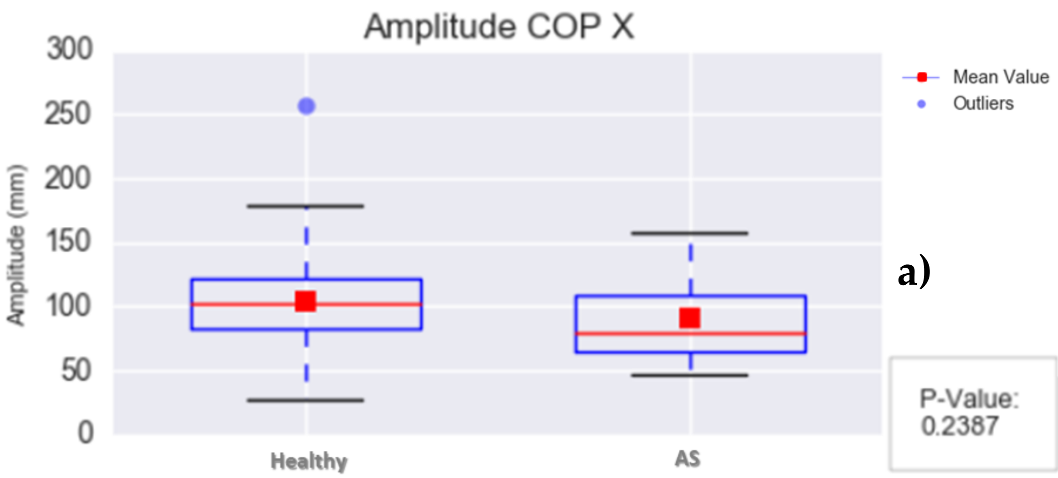
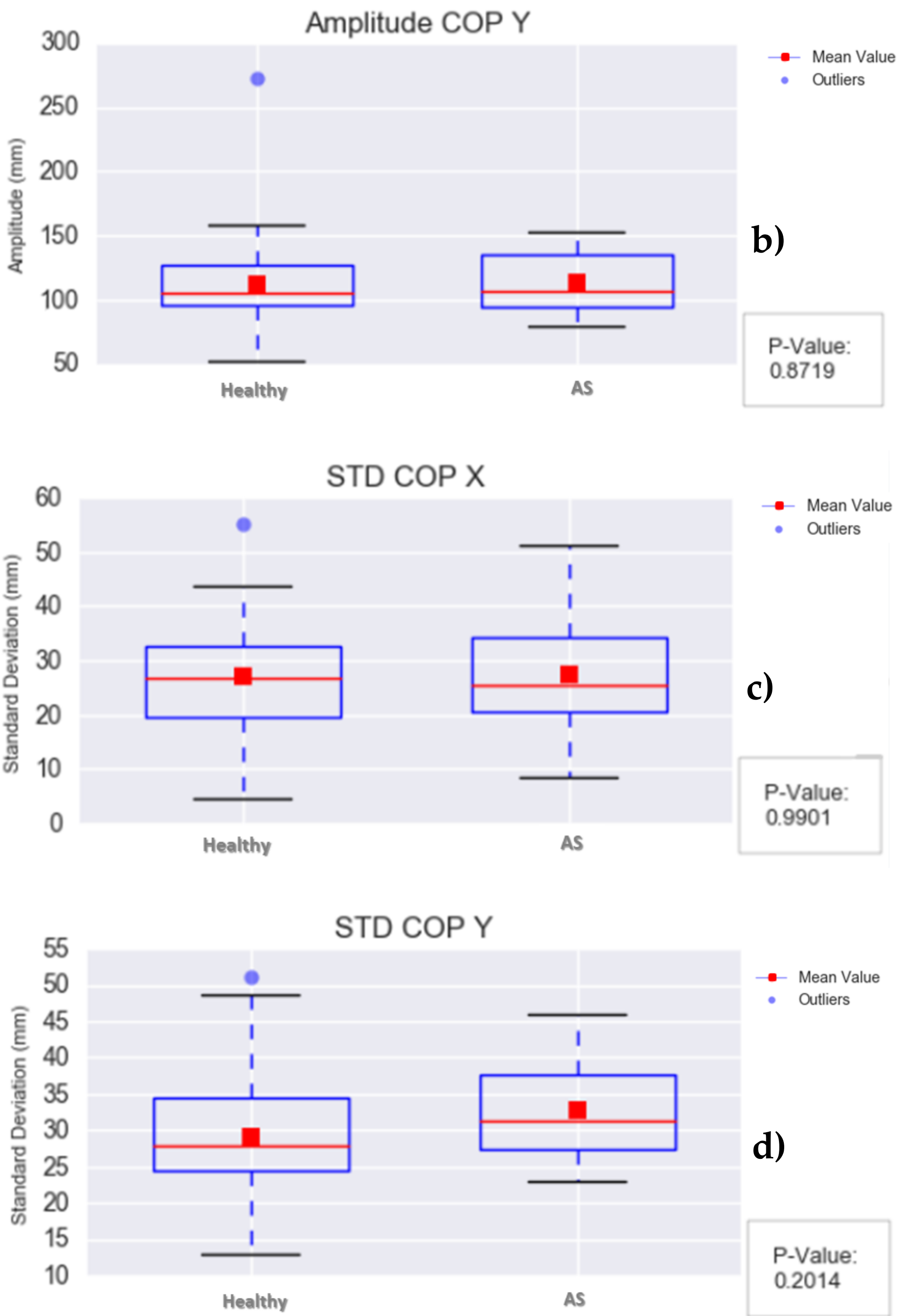
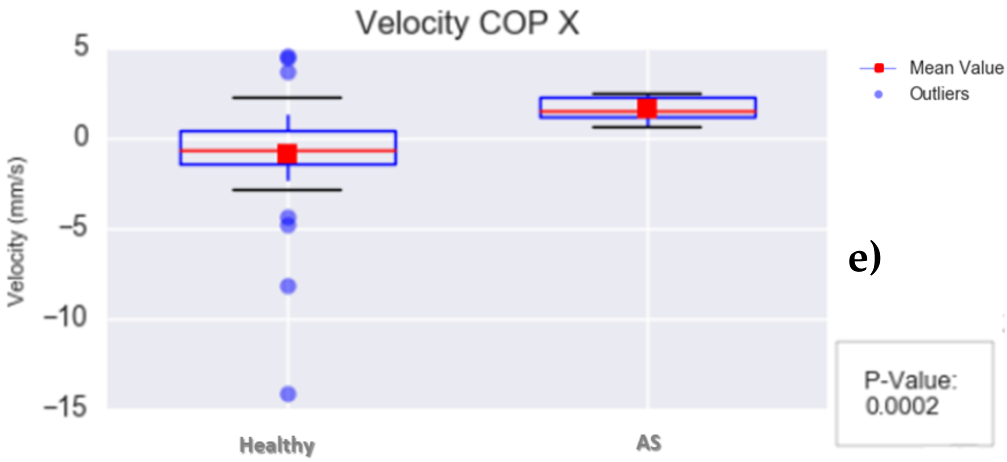


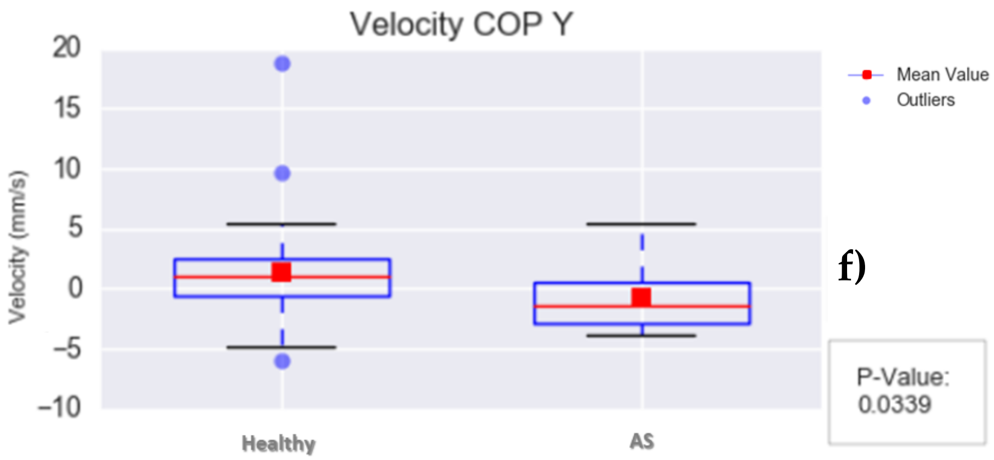
Figure J.4.7 – COP parameters evaluation during RR (Reach Right) task. a) COP's amplitude in X direction; b) COP's amplitude in Y direction; c) COP's standard deviation in X direction; d) COP's standard deviation in Y direction; e) Mean Velocity of COP displacement in X direction; f) Mean Velocity of COP displacement in Y direction; g) Area of COP displacement.

RL




Amplitude COP Y
Amplitude (mm)
300
250
200
150
100
50
Healthy
AS
Mean Value
Outliers
b)
P-Value:
0.8719
STD COP X
Standard Deviation (mm)
60
50
40
30
20
10
0
Healthy
AS
Mean Value
Outliers
c)
P-Value:
0.9901
STD COP Y
Standard Deviation (mm)
55
50
45
40
35
30
25
20
15
10
Healthy
AS
Mean Value
Outliers
d)
P-Value:
0.2014





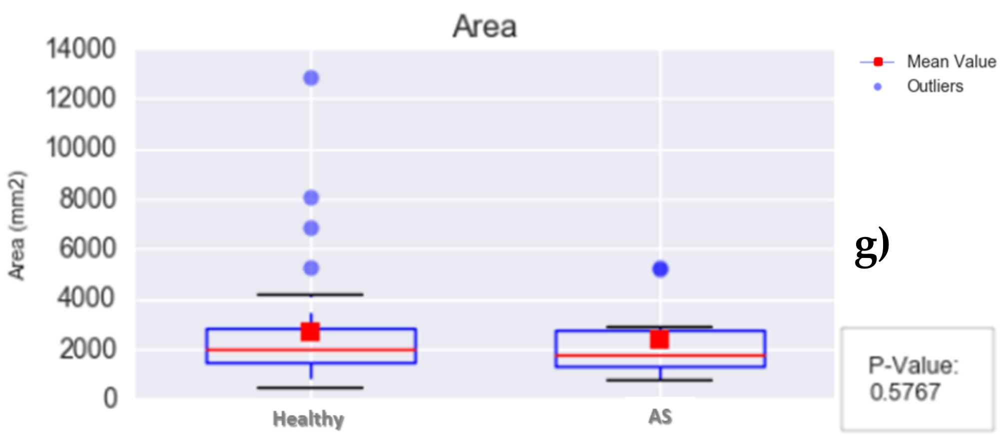
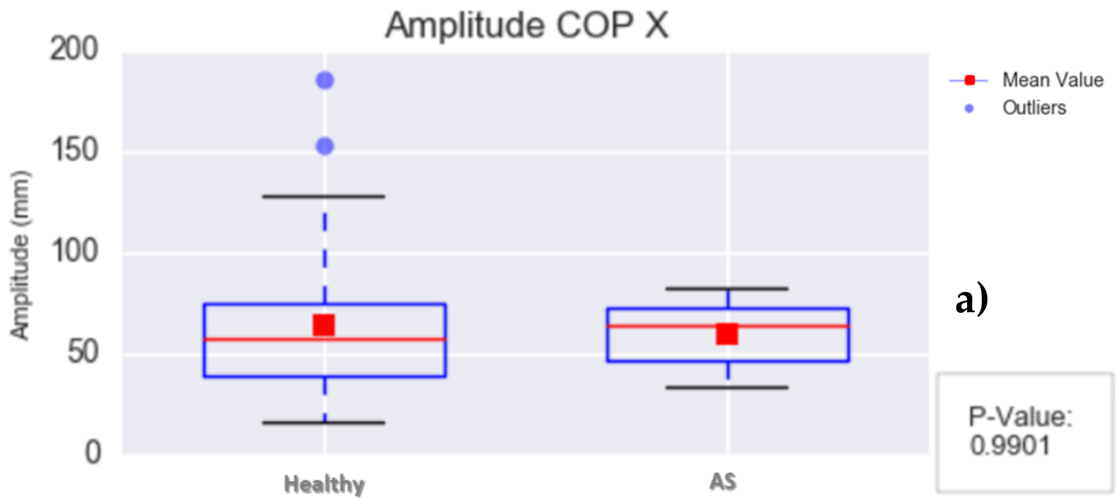
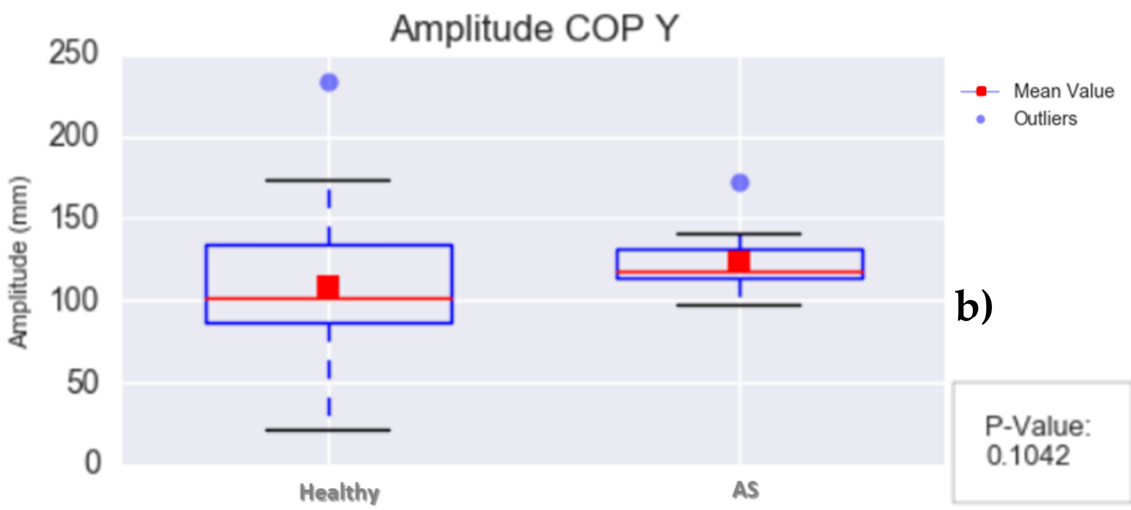


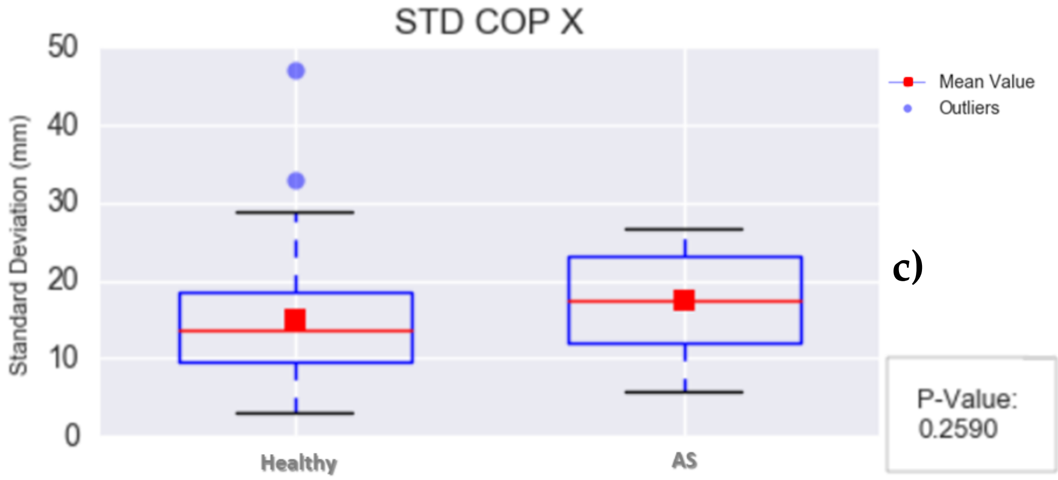
Figure J.4.8 – COP parameters evaluation during RL (Reach Left) task. a) COP's amplitude in X direction; b) COP's amplitude in Y direction; c) COP's standard deviation in X direction; d) COP's standard deviation in Y direction; e) Mean Velocity of COP displacement in X direction; f) Mean Velocity of COP displacement in Y direction; g) Area of COP displacement.


Amplitude COP X
Amplitude (mm)
200
150
100
50
0
Healthy
AS
Mean Value
Outliers
P-Value:
0.9901

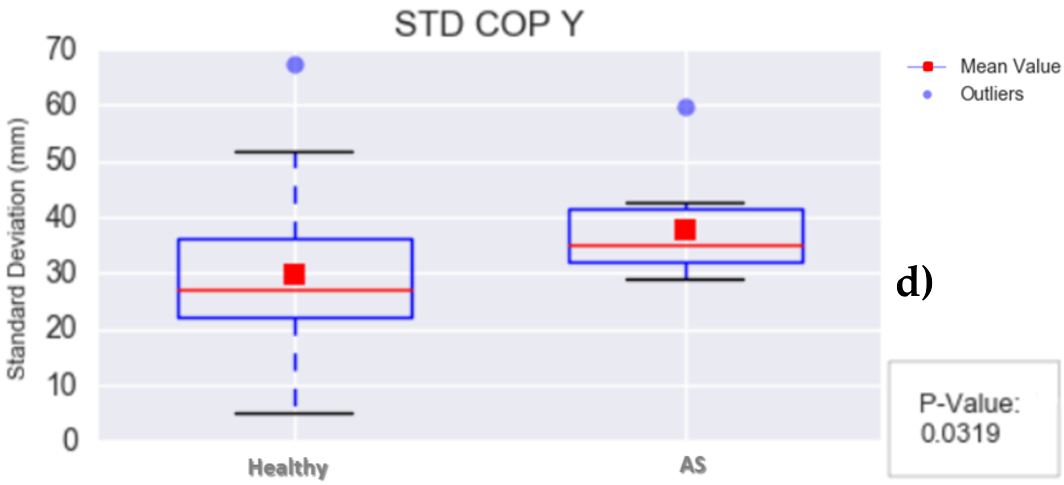
a)


Amplitude COP Y
Amplitude (mm)
250
200
150
100
50
0
Healthy
AS
Mean Value
Outliers
P-Value:
0.1042

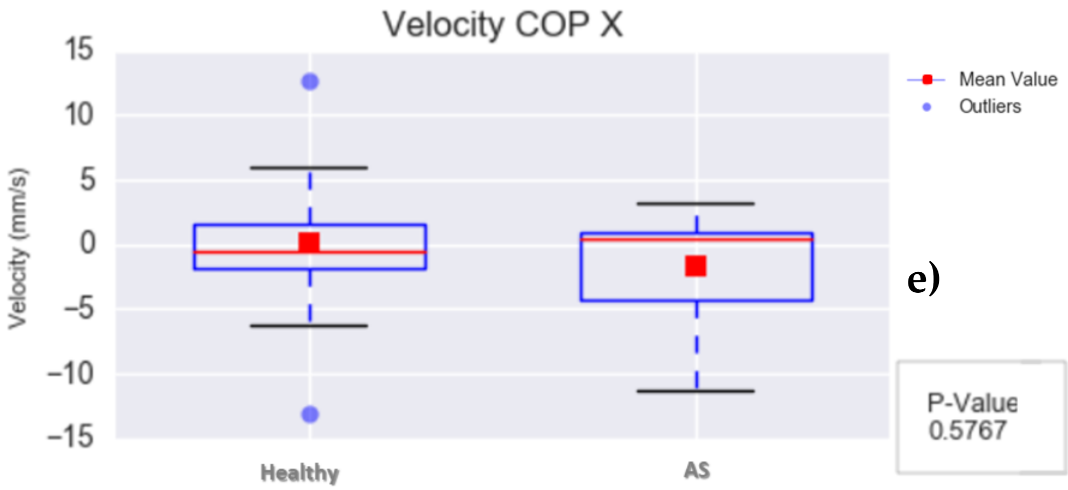
b)


STD COP X
Standard Deviation (mm)
50
40
30
20
10
0
Healthy
AS
Mean Value
Outliers
P-Value:
0.2590

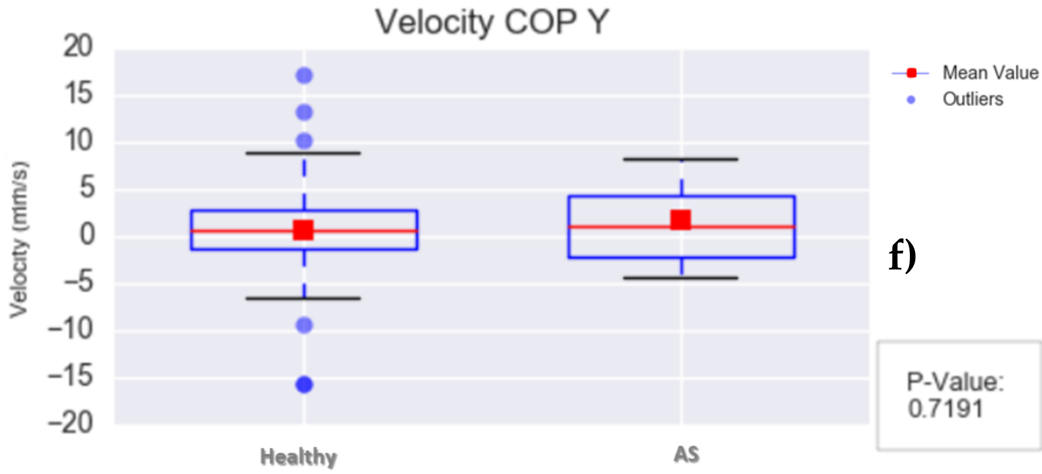
c)


STD COP Y
Standard Deviation (mm)
70
60
50
40
30
20
10
0
Healthy
AS
Mean Value
Outliers
P-Value:
0.0319

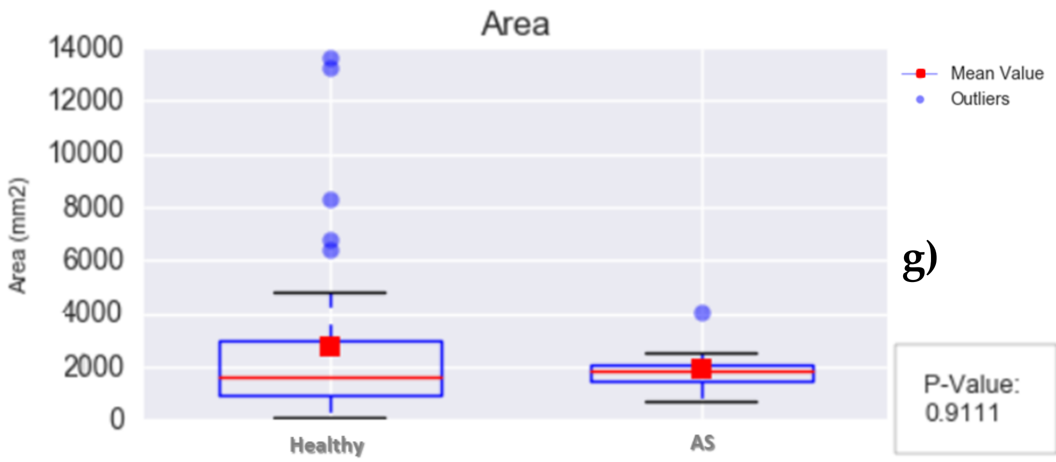
d)


Velocity COP X
Velocity (mm/s)
15
10
5
0
−5
−10
−15
Healthy
AS
Mean Value
Outliers
P-Value
0.5767

e)



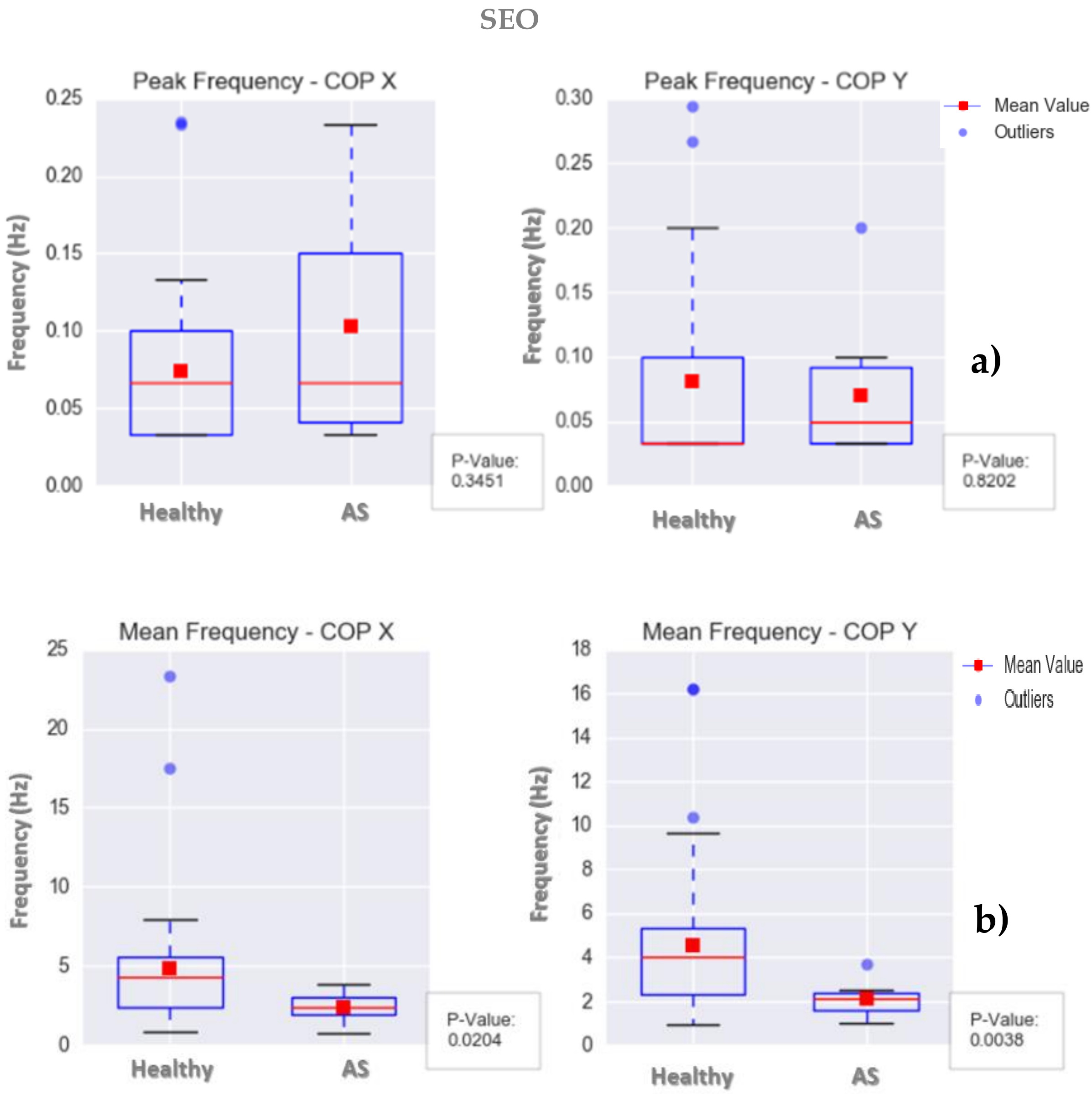
f)



g)

Figure J.4.9 – COP parameters evaluation during RC (Reach Center) task. a) COP's amplitude in X direction; b) COP's amplitude in Y direction; c) COP's standard deviation in X direction; d) COP's standard deviation in Y direction; e) Mean Velocity of COP displacement in X direction; f) Mean Velocity of COP displacement in Y direction; g) Area of COP displacement.

J.5 – COP Frequencies



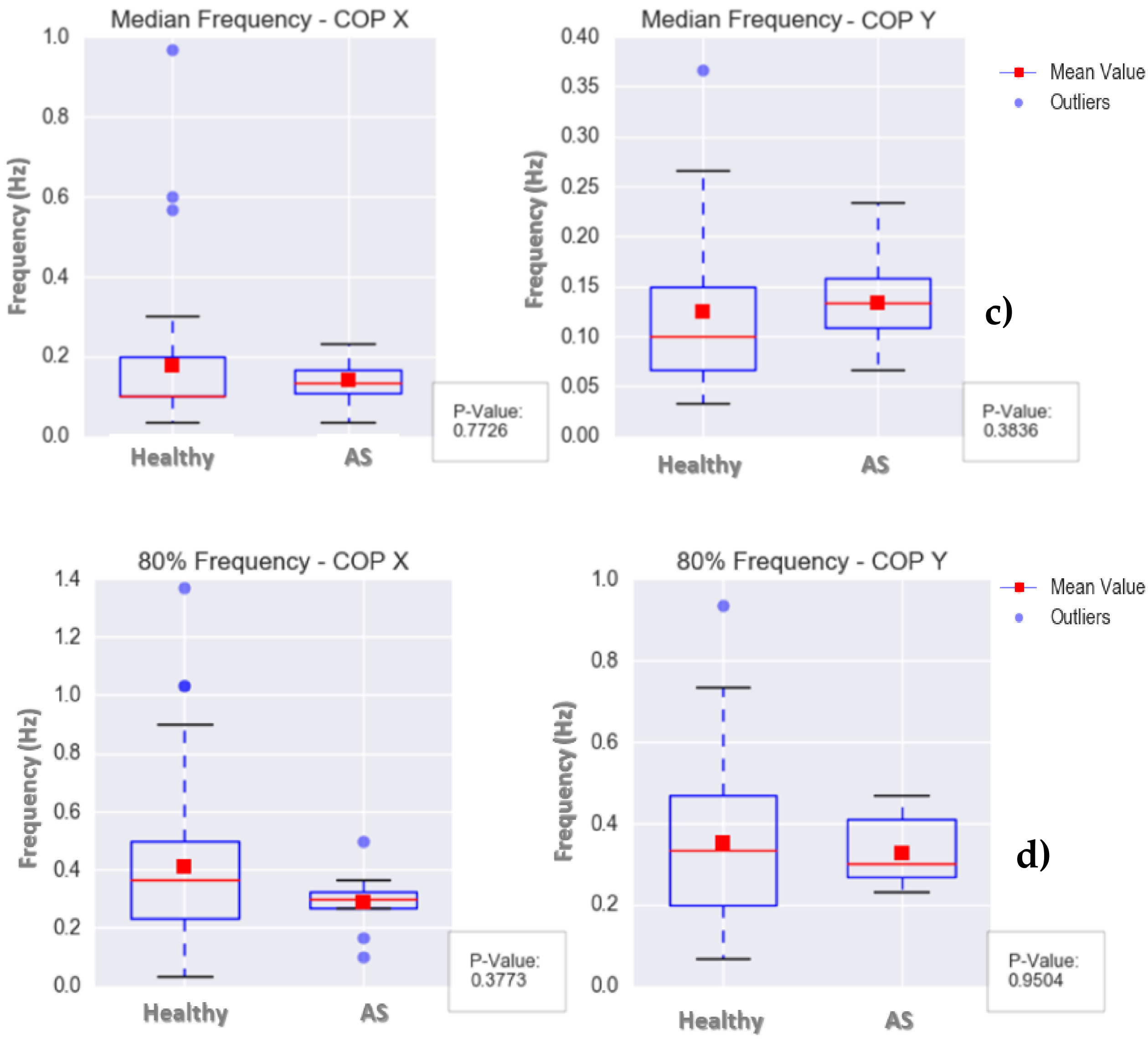
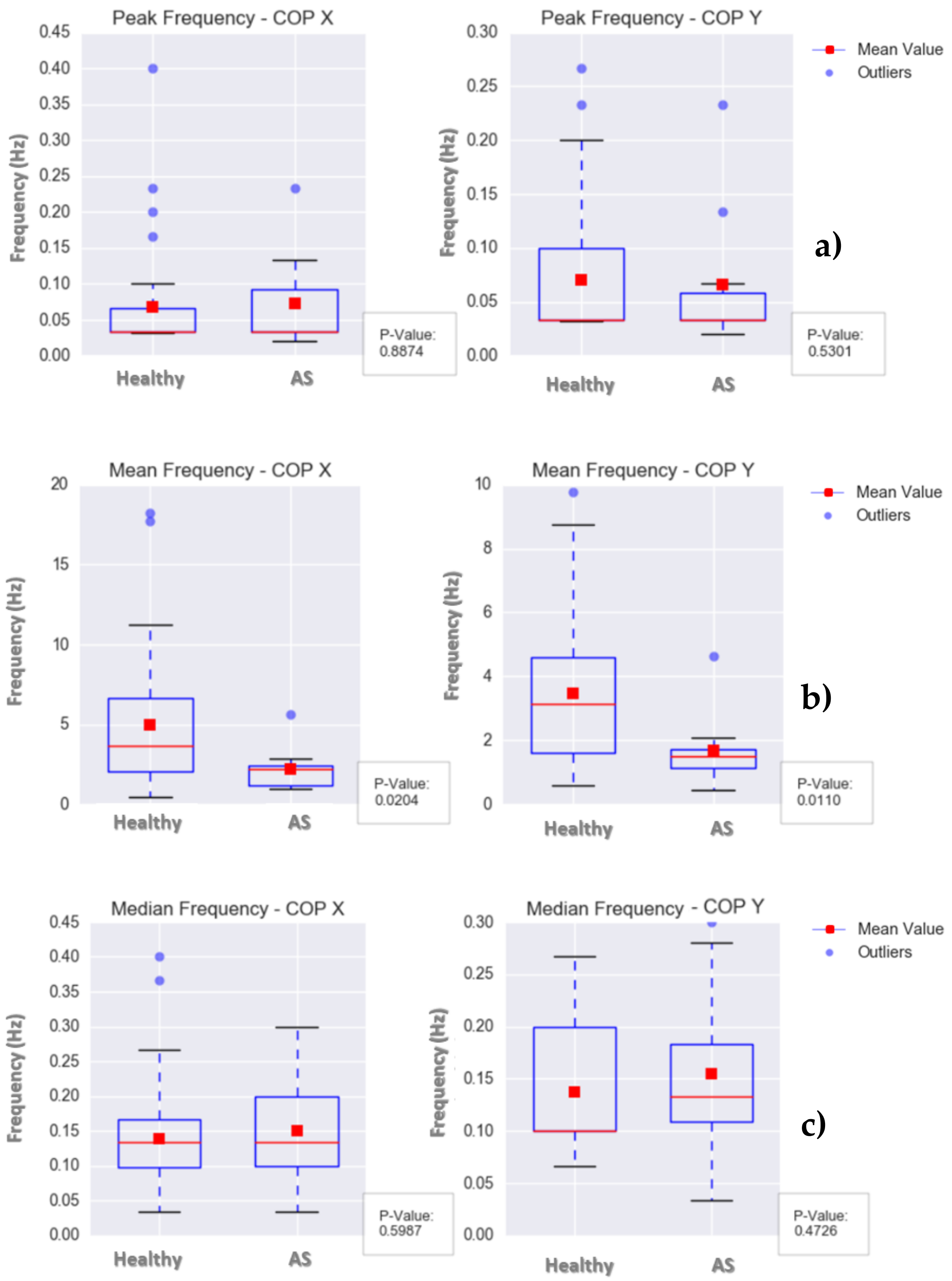


Figure J.5.1 – COP frequencies evaluation during SEO (Standing Eyes Open) task. a) Peak frequency of COP displacement in both directions; b)Mean frequency of COP displacement in both directions; c) Median frequency of COP displacement in both directions; d) Frequency at 80% of power spectrum of COP displacement in both directions.

SEC



Peak Frequency - COP X
Peak Frequency - COP Y
Frequency (Hz)
Healthy
AS
P-Value: 0.8874
P-Value: 0.5301
Mean Value
Outliers
a)
Mean Frequency - COP X
Mean Frequency - COP Y
P-Value: 0.0204
P-Value: 0.0110
b)
Median Frequency - COP X
Median Frequency - COP Y
P-Value: 0.5987
P-Value: 0.4726
c)

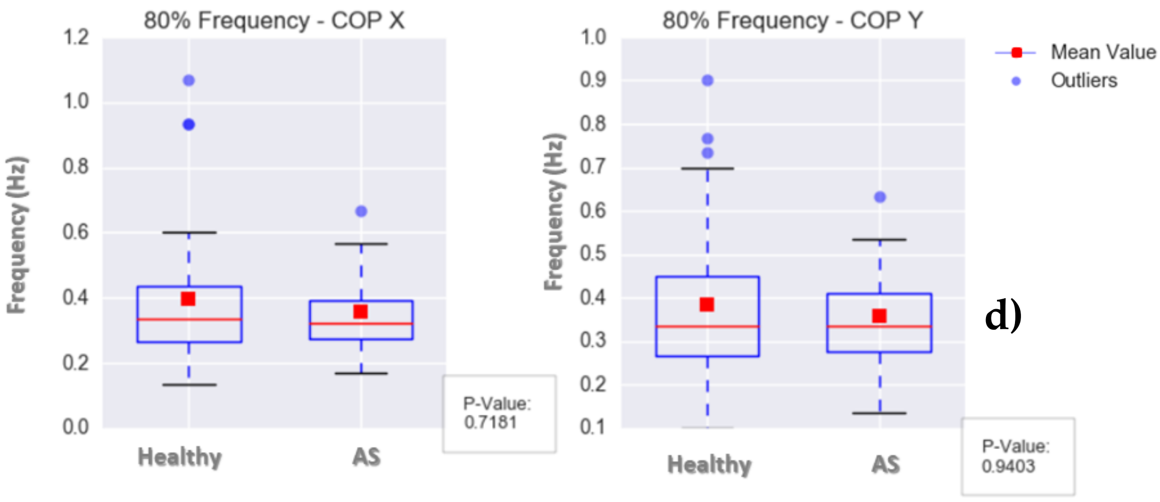
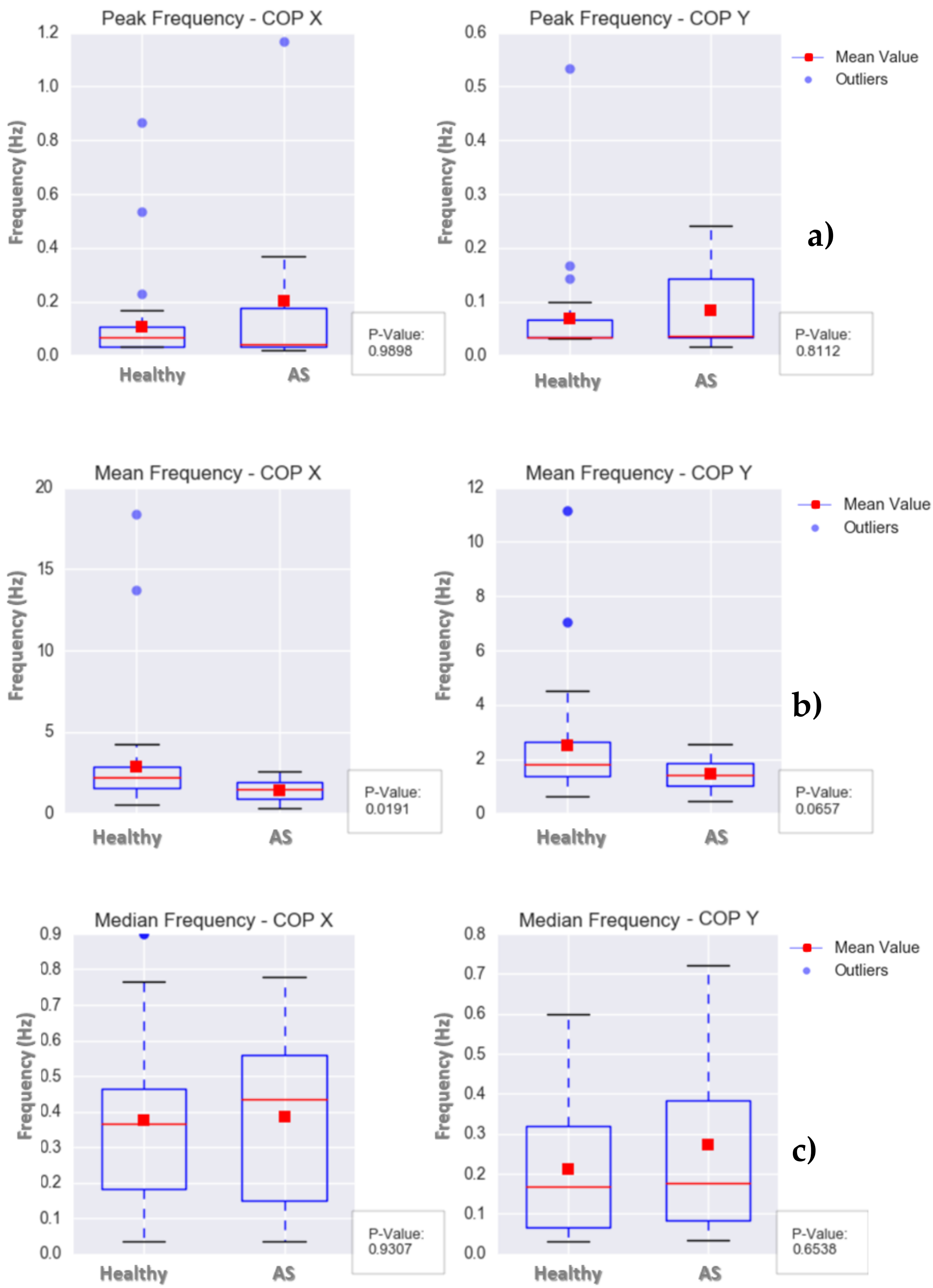


Figure J.5.2 – COP frequencies evaluation during SEC (Standing Eyes Close) task. a) Peak frequency of COP displacement in both directions; b)Mean frequency of COP displacement in both directions; c) Median frequency of COP displacement in both directions; d) Frequency at 80% of power spectrum of COP displacement in both directions.

RFEO



Peak Frequency - COP X
Frequency (Hz)
Healthy
AS
P-Value: 0.9898
Peak Frequency - COP Y
Frequency (Hz)
Mean Value
Outliers
a)
P-Value: 0.8112
Mean Frequency - COP X
Frequency (Hz)
P-Value: 0.0191
Mean Frequency - COP Y
Frequency (Hz)
b)
P-Value: 0.0657
Median Frequency - COP X
Frequency (Hz)
P-Value: 0.9307
Median Frequency - COP Y
Frequency (Hz)
c)
P-Value: 0.6538

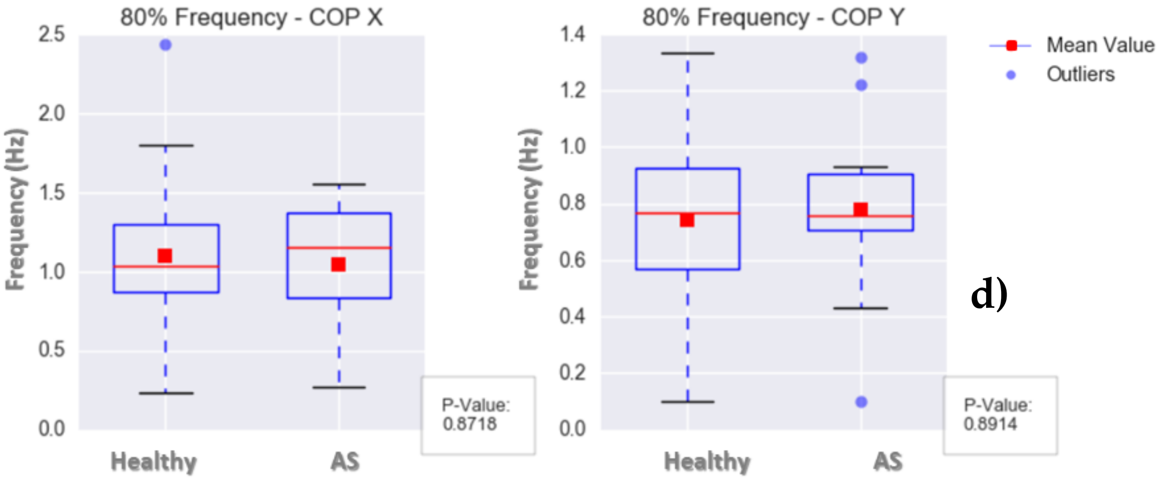
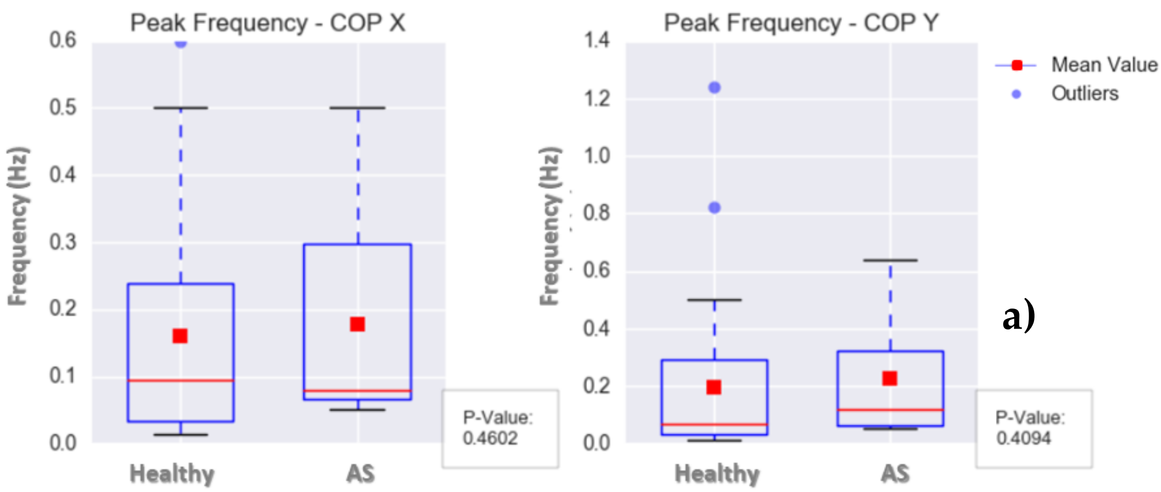


Figure J.5.3 – COP frequencies evaluation during RFEO (Right Foot Standing Eyes Open) task. a) Peak frequency of COP displacement in both directions; b)Mean frequency of COP displacement in both directions; c) Median frequency of COP displacement in both directions; d) Frequency at 80% of power spectrum of COP displacement in both directions.

RFEC



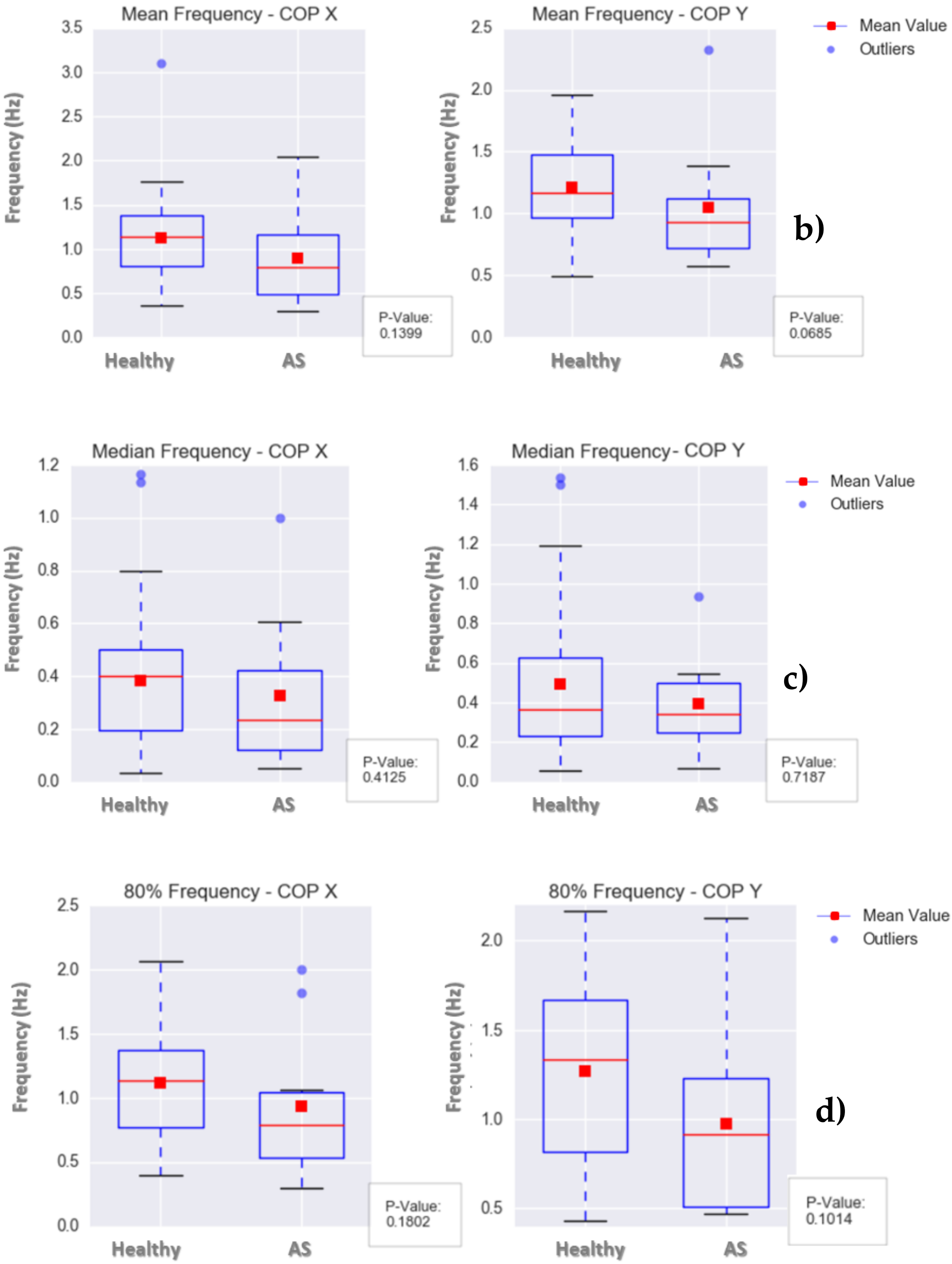
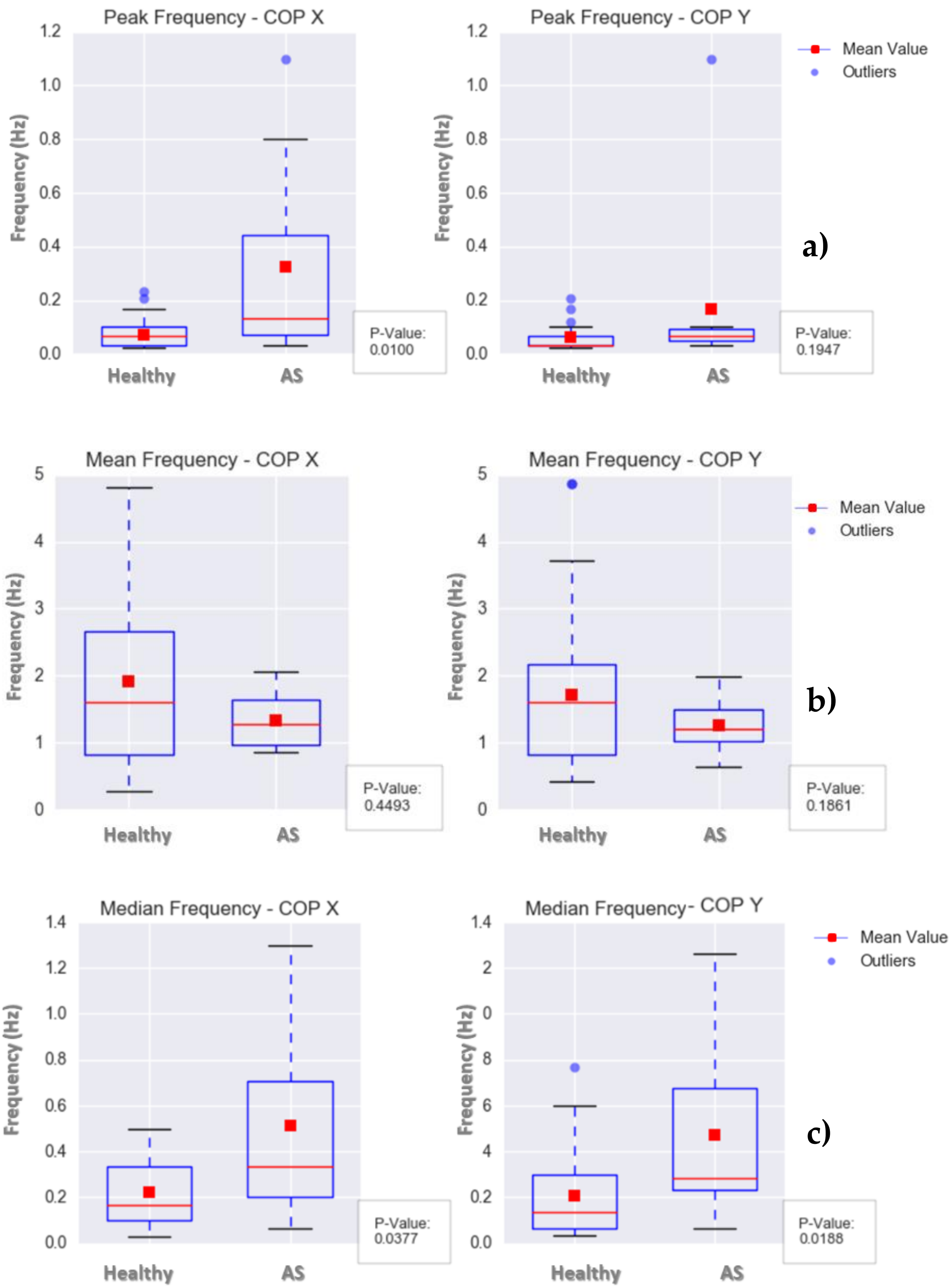


Figure J.5.4 – COP frequencies evaluation during RFEC (Right Foot Standing Eyes Close) task. a) Peak frequency of COP displacement in both directions; b)Mean frequency of COP displacement in both directions; c) Median frequency of COP displacement in both directions; d) Frequency at 80% of power spectrum of COP displacement in both directions.



Peak Frequency - COP X
Frequency (Hz)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Healthy
AS
P-Value:
0.0100
Peak Frequency - COP Y
Frequency (Hz)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Healthy
AS
P-Value:
0.1947
Mean Value
Outliers
a)
Mean Frequency - COP X
Frequency (Hz)
5
4
3
2
1
0
Healthy
AS
P-Value:
0.4493
Mean Frequency - COP Y
Frequency (Hz)
5
4
3
2
1
0
Healthy
AS
P-Value:
0.1861
Mean Value
Outliers
b)
Median Frequency - COP X
Frequency (Hz)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Healthy
AS
P-Value:
0.0377
Median Frequency- COP Y
Frequency (Hz)
1.4
2
0
8
6
4
0.2
0.0
Healthy
AS
P-Value:
0.0188
Mean Value
Outliers
c)

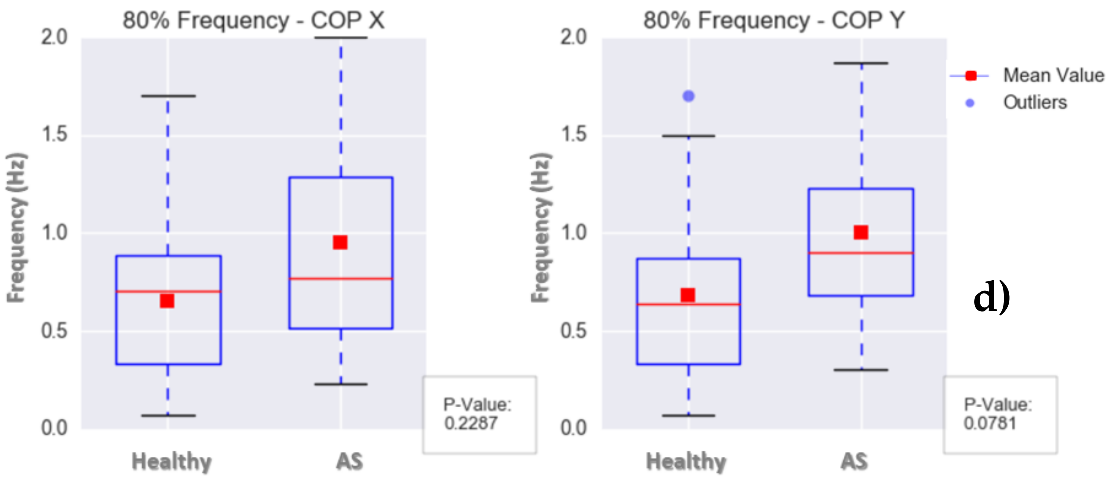
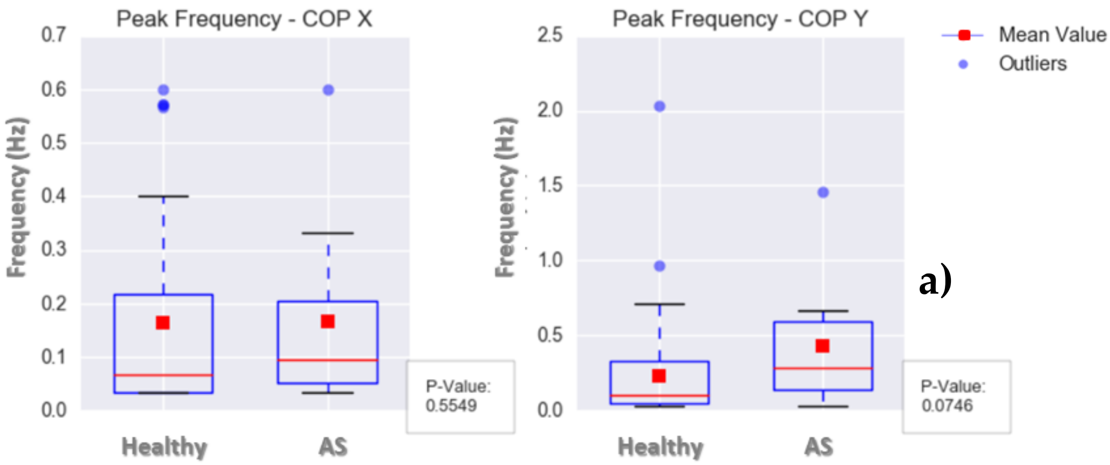
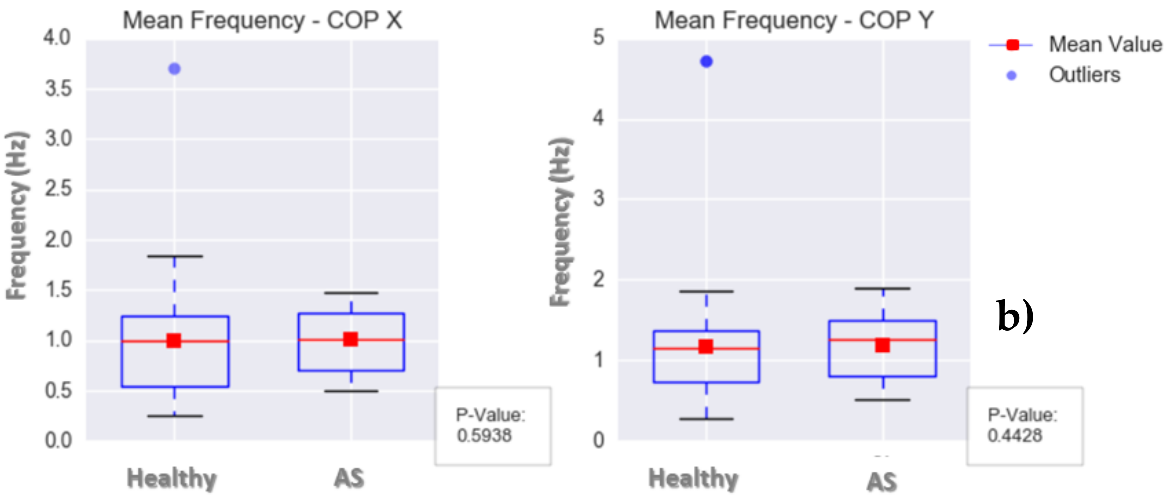


Figure J.5.5 – COP frequencies evaluation during LFEO (Left Foot Standing Eyes Open) task. a) Peak frequency of COP displacement in both directions; b)Mean frequency of COP displacement in both directions; c) Median frequency of COP displacement in both directions; d) Frequency at 80% of power spectrum of COP displacement in both directions.

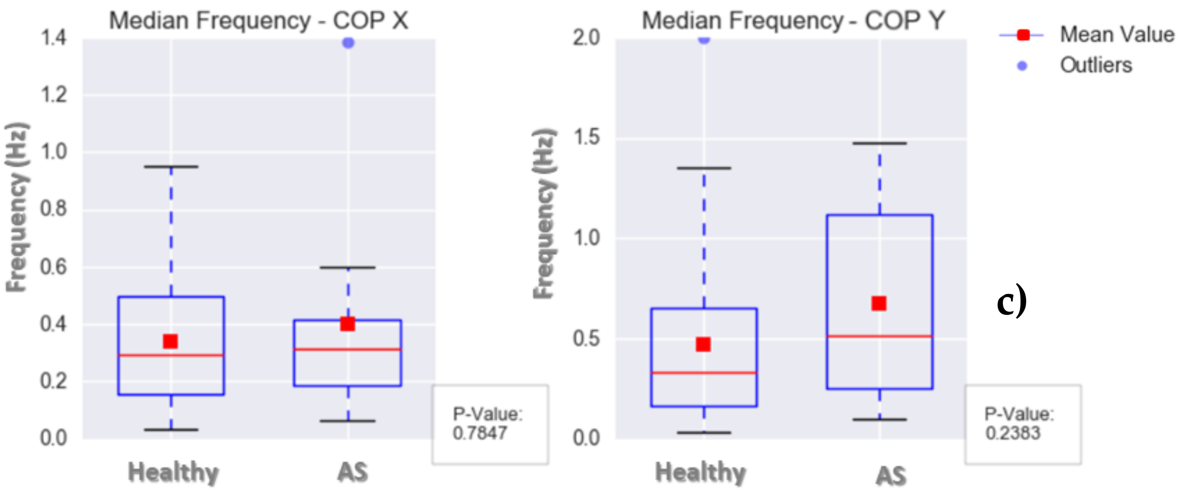
LFEC





Mean Frequency - COP X
Frequency (Hz)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Healthy
AS
P-Value:
0.5938
Mean Frequency - COP Y
Frequency (Hz)
5
4
3
2
1
0
Healthy
AS
P-Value:
0.4428
Mean Value
Outliers

b)



Median Frequency - COP X
Frequency (Hz)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Healthy
AS
P-Value:
0.7847
Median Frequency - COP Y
Frequency (Hz)
2.0
1.5
1.0
0.5
0.0
Healthy
AS
P-Value:
0.2383
Mean Value
Outliers

c)

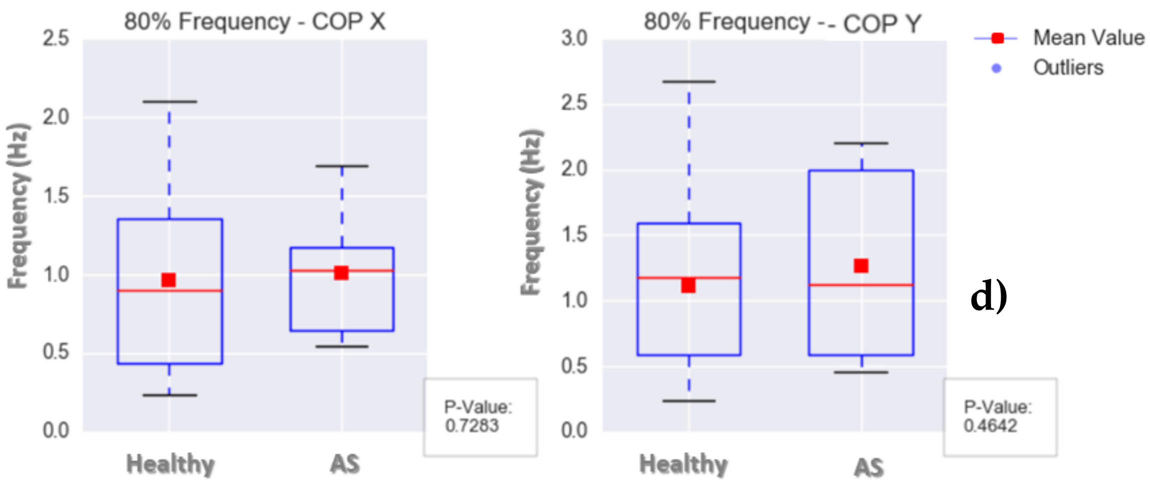
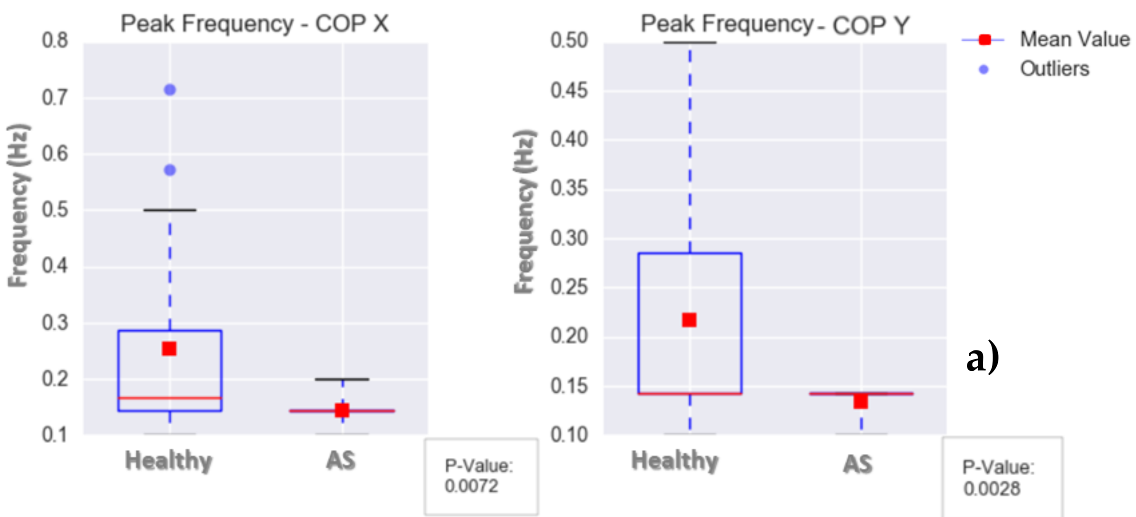
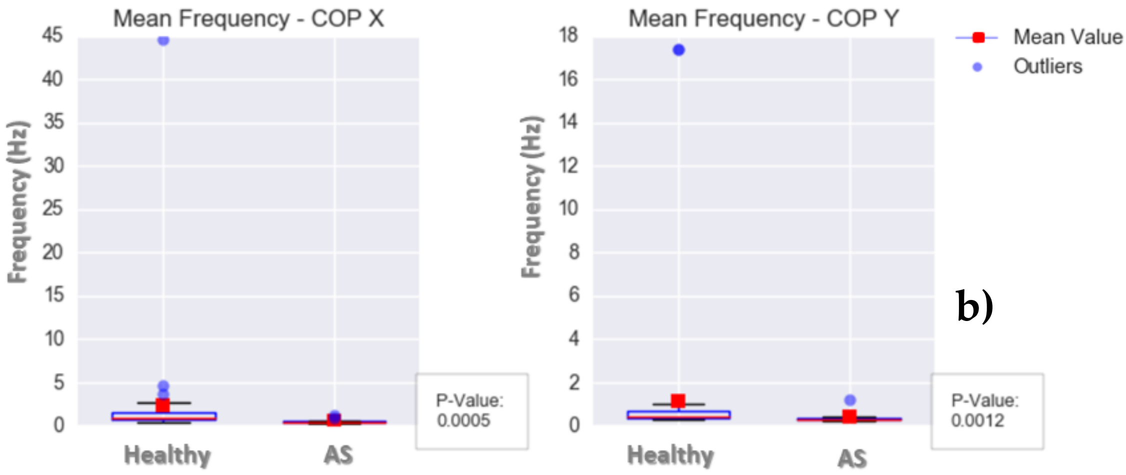


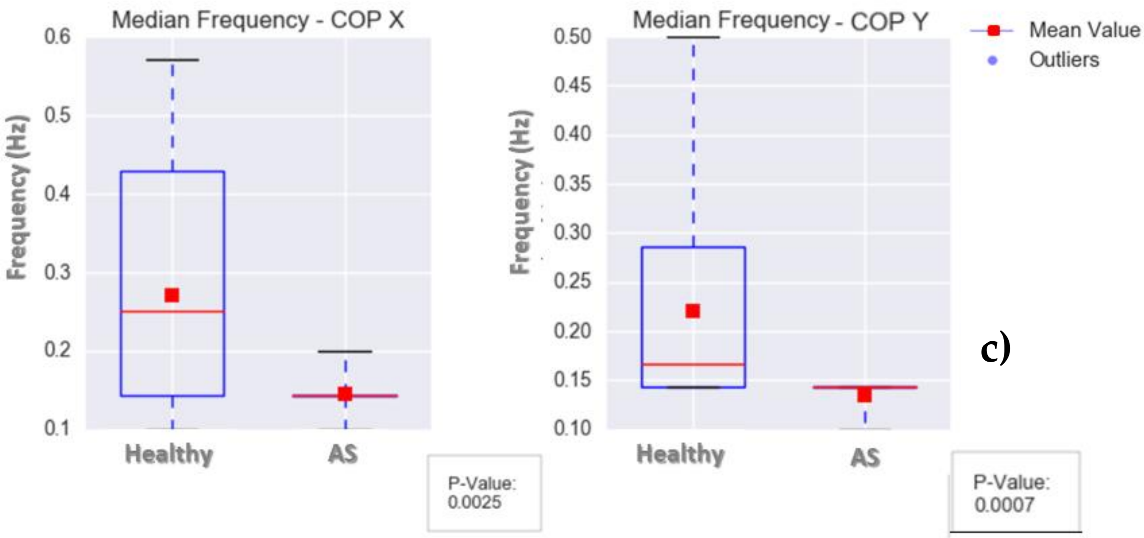
Figure J.5.6 – COP frequencies evaluation during LFEC (Left Foot Standing Eyes Close) task. a) Peak frequency of COP displacement in both directions; b)Mean frequency of COP displacement in both directions; c) Median frequency of COP displacement in both directions; d) Frequency at 80% of power spectrum of COP displacement in both directions.

RR




Mean Frequency - COP X
Frequency (Hz)
45
40
35
30
25
20
15
10
5
0
Healthy
AS
P-Value:
0.0005
Mean Frequency - COP Y
Frequency (Hz)
18
16
14
12
10
8
6
4
2
0
Healthy
AS
P-Value:
0.0012
Mean Value
Outliers

b)


Median Frequency - COP X
Frequency (Hz)
0.6
0.5
0.4
0.3
0.2
0.1
Healthy
AS
P-Value:
0.0025
Median Frequency - COP Y
Frequency (Hz)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
Healthy
AS
P-Value:
0.0007
Mean Value
Outliers

c)

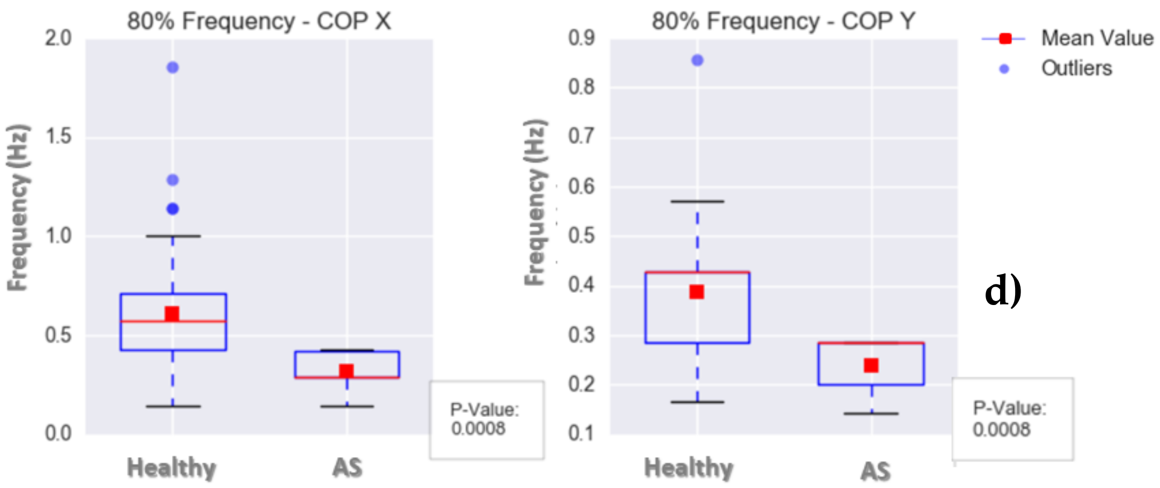
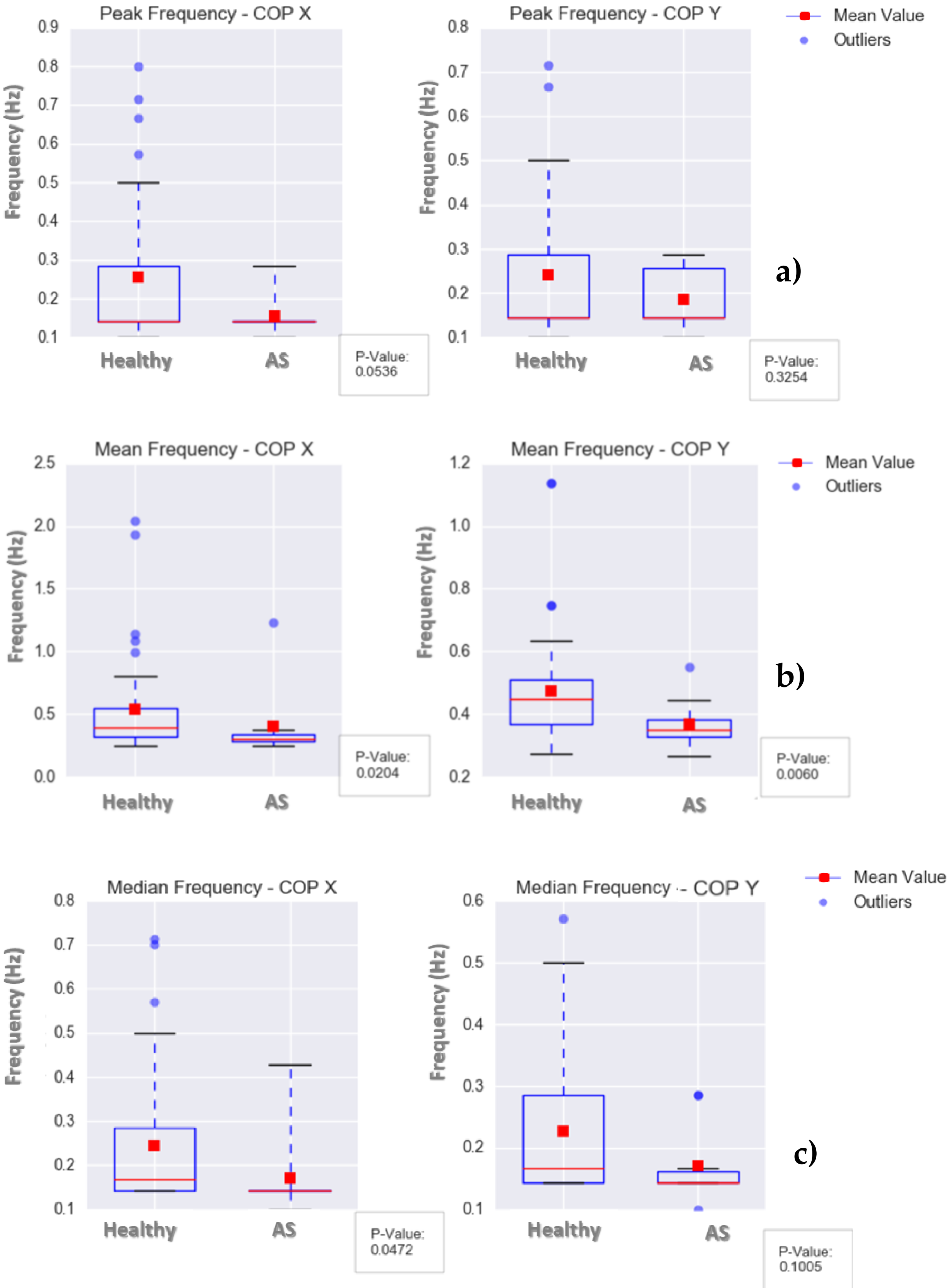


Figure J.5.7 – COP frequencies evaluation during RR (Reach Right) task. a) Peak frequency of COP displacement in both directions; b)Mean frequency of COP displacement in both directions; c) Median frequency of COP displacement in both directions; d) Frequency at 80% of power spectrum of COP displacement in both directions.

RL



Peak Frequency - COP X
Frequency (Hz)
Healthy
AS
P-Value: 0.0536
Peak Frequency - COP Y
Frequency (Hz)
Healthy
AS
P-Value: 0.3254
Mean Value
Outliers
a)
Mean Frequency - COP X
Frequency (Hz)
Healthy
AS
P-Value: 0.0204
Mean Frequency - COP Y
Frequency (Hz)
Healthy
AS
P-Value: 0.0060
Mean Value
Outliers
b)
Median Frequency - COP X
Frequency (Hz)
Healthy
AS
P-Value: 0.0472
Median Frequency - COP Y
Frequency (Hz)
Healthy
AS
P-Value: 0.1005
Mean Value
Outliers
c)

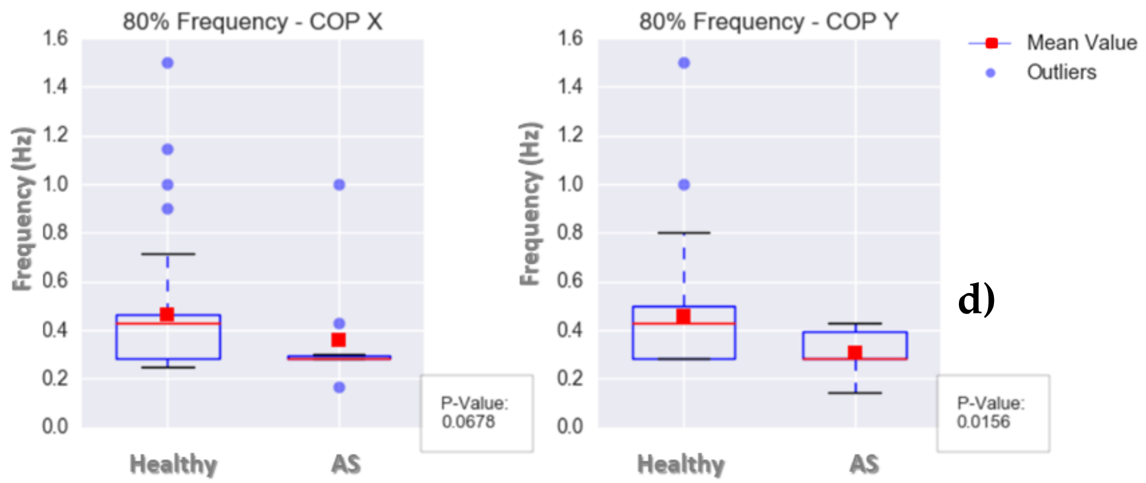
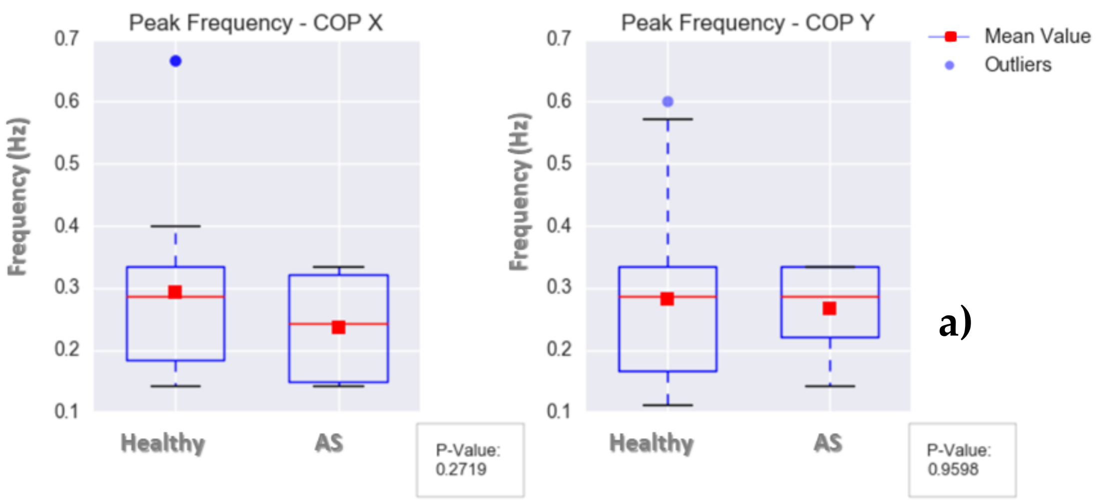
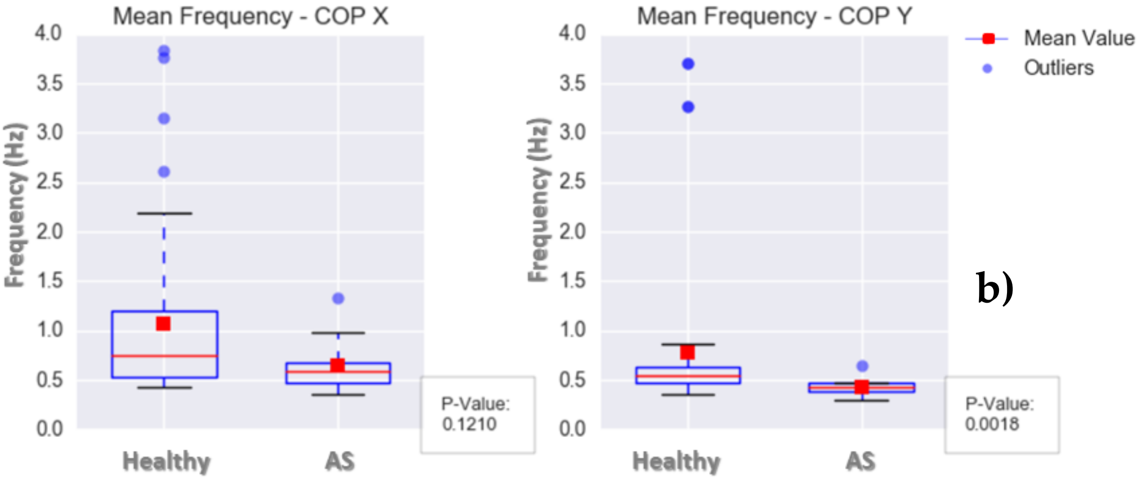


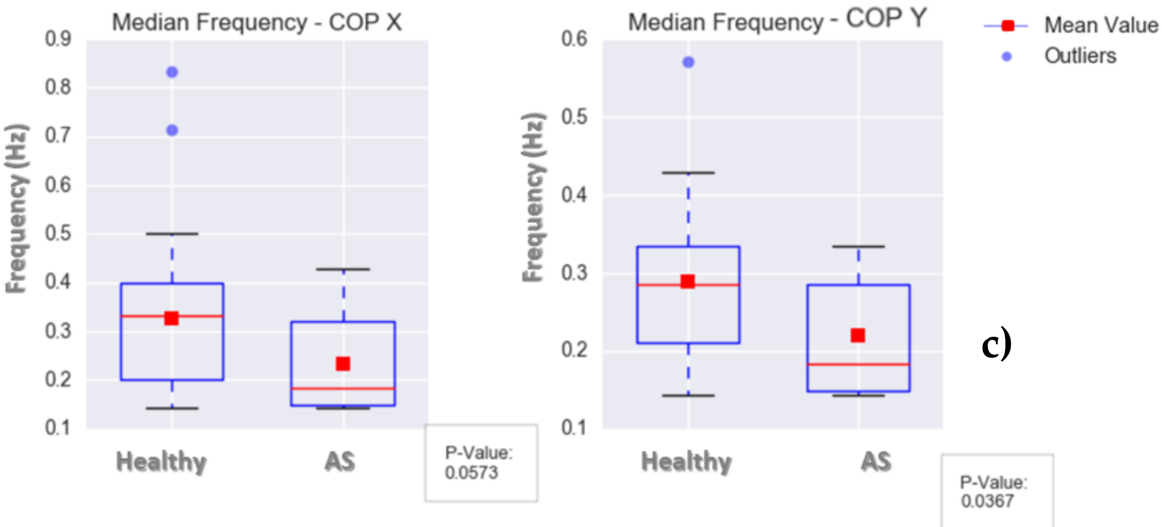
Figure J.5.8 – COP frequencies evaluation during RL (Reach Left) task. a) Peak frequency of COP displacement in both directions; b)Mean frequency of COP displacement in both directions; c) Median frequency of COP displacement in both directions; d) Frequency at 80% of power spectrum of COP displacement in both directions.

RC




Mean Frequency - COP X
Mean Frequency - COP Y
Frequency (Hz)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Healthy
AS
P-Value:
0.1210
P-Value:
0.0018
Mean Value
Outliers

b)


Median Frequency - COP X
Median Frequency - COP Y
Frequency (Hz)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Healthy
AS
P-Value:
0.0573
P-Value:
0.0367
Mean Value
Outliers

c)

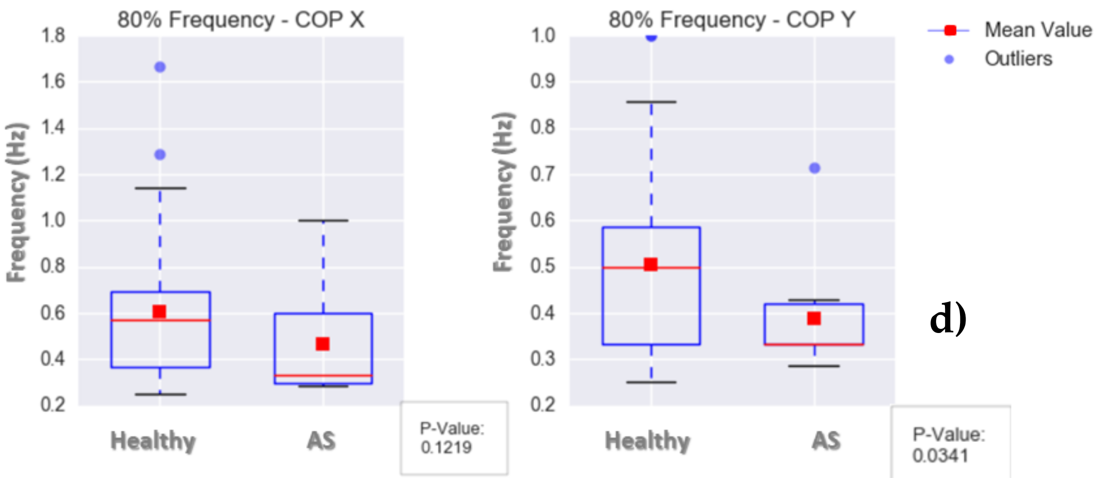


Figure J.5.9 – COP frequencies evaluation during RC (Reach Center) task. a) Peak frequency of COP displacement in both directions; b)Mean frequency of COP displacement in both directions; c) Median frequency of COP displacement in both directions; d) Frequency at 80% of power spectrum of COP displacement in both directions.

K

Appendix K

Devalopment of a normative base using posturography and electromyography for rheumatologic diseases

Mendes. $A^{1,2}$, Gamboa. $H^{1,2}$, Osório. $D^{1,2}$, and Quaresma. $C^{1,2}$

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Introduction: Controlling posture and keeping balance are fundamental tasks for the maintenance of upright position and consequently for doing daily activities of daily life [1]. So, the postural control system and the neuromuscular system play a very important role in maintaining balance and posture. However, these systems may be affected for a number of reasons, for example rheumatologic diseases [2]. Postural control tests performed to date are inconclusive with an unclear methodology, and present different results depending on the health professional that perform them [3].

Objectives: The main objectives of this project is the standardization of posturography tests, and with the help of electromyography, define the normal pattern of postural adjustments of the standing position.

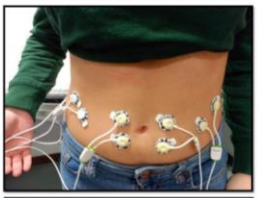
1. Sample:

- 50 healthy people.

2. Methodology:

Muscles evaluated throughout the protocol:

- *Rectus Abdominis;*
- *Obliques;*
- *Ilicostalis;*
- *Multifidus.*

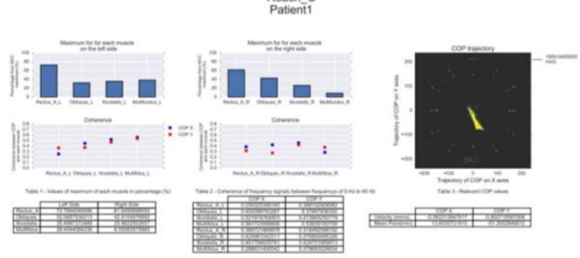


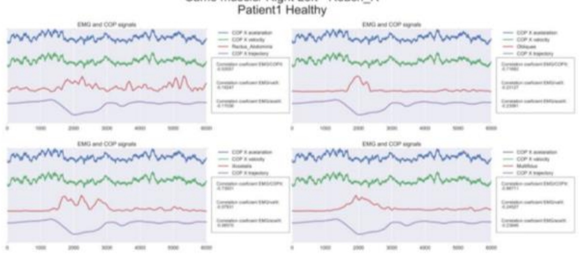
3. Protocol:

- Rest (15 seconds);
- MVC (Maximum Voluntary Contraction);
- Task set to evaluate postural control:
  - Standing, with eyes open and eyes close (30 seconds each);
  - One foot standing (right and left) with eyes open and eyes close (30 seconds each);
  - Reaching an object at hip height (center, left and right);
  - Reaching an object at knee height.

4. Data Analysis:

Data analysis was done in *Python*. To see if there is some pattern and to see if there is some correlation between EMG data and platform data, it was constructed some graphics.





5. Conclusions:

- Were analyzed 2 healthy subjects;
- Greater trajectory of COP means greater muscle activation;
- Tasks of reaching objects have higher correlations between the COP trajectory and the EMG signal;
- Tasks that do not require much movement have lower correlations, due to the low muscle activation and low COP movement.

References:

[1] DUARTE, Marcos, et al. Revisão sobre posturografia baseada em plataforma de força para avaliação do equilíbrio. *Revista Brasileira de Fisioterapia*, 2010, 14.3: 183-192.

[2] PALMIERI, Riann M., et al. Center-of-pressure parameters used in the assessment of postural control. *Journal of Sport Rehabilitation*, 2002, 11.1: 51-66.

[3] TAYLOR, Melissa R., et al. Subtle differences during posturography testing can influence postural sway results: The effects of talking, time before data acquisition, and visual fixation. *Journal of applied biomechanics*, 2015, 31.5: 324-329

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