# *The physical rehabilitation of muscle weakness and lost quality of movement in patients with multiple sclerosis*

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# The physical rehabilitation of muscle weakness and lost quality of movements in patients with multiple sclerosis

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# ABSTRACT

The objective of this study was to evaluate the effects of five physical therapy intervention protocols (control, micro current electrical therapy, resistance, resistance plus electro stimulation, whole body vibration) on strength and coordination in the inferior extremities in 41 patients with multiple sclerosis in a 10-week intervention period. For the analysis were created 10 groups of variables with similar characteristics corresponding to variables of coordination and strength. For each group was fitted a repeated measures marginal model considering the different variables for each group as a within-subject factor. Based in the models proposed it was found the Isometric outcomes present significant differences between the control and the treatment Micro current Electrical Stimulation and whole body vibration. The models fitted for each group of outcome variables could be used for physical therapy researcher to design future studies in physical rehabilitation of multiple sclerosis patients involving measures in strength and coordination in the inferior extremities.

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*To my wife Olga and my kid  Sara, this is for you and with you , we are building the future, the sacrifice shall be rewarded on time.*

*For all only I can say “ Gracias”.*

**TABLE OF CONTENTS**

## LIST OF TABLES

## LIST OF FIGURES IN APPENDIX

## LIST OF TABLES IN APPENDIX

## 1. INTRODUCTION, OBJECTIVE, METHODS AND MATERIALS

### 1.1. INTRODUCTION

“Multiple sclerosis (MS) is a disease that affects the central nervous system, which includes the brain, spinal cord, and optic nerves.

The clinical symptoms and deficits are quite varied among persons with MS, and they typically change (and worsen) as the disease evolves. The most frequent include : Fatigue, Motor involvement (weakness in an affected limb, progressing to spasticity, hyper-reflexia, clonus, extensor plantar responses,and muscle contractures) Visual involvement( blurring or haziness, which can progress to vision loss. Periorbital pain often occurs, and optic neuritis is a common presenting symptom), Sensory symptoms (squeezing and burning sensations, or numbness and paresthesias), Tonic spasms ( increases in flexor tone in one or more limbs), Brainstem symptoms (ophthalmoplegia and nystagmus, Vertigo weakness and pain), Cerebellar involvement (intention tremor, truncal ataxia and ataxia of gait, dysarthria and “scanning speech.”) Genitourinary symptoms (urinary urgency, frequency, incontinence, hesitancy and retention, and urinary tract infections) Bowel dysfunction, (constipation) , Cognitive deficits (short-term memory dysfunction, difficulty managing complex tasks, and confusion) , and Depression”. (Holland N. J.,2006)

“The role of the physical therapy in the rehabilitation and treatment of the multiple sclerosis patient consist in the evaluation and intervention in ambulation, mobility, posture, trunk control, balance transfers, range of motion, motor function and neurological function.

Particularly for the motor function and neurological function , The therapist should assess gross strength, with emphasis on *function*, in the extremities and trunk as well as the coordination ( gross, fine, rapid alternating)” (Provance P. 2006) .

## 1.2. OBJECTIVE OF THE STUDY

The objective of this study was to evaluate the effects of
Five physical therapy intervention protocols (control, micro current electrical therapy, resistance, resistance plus electro stimulation, whole body vibration) on strength and coordination in the inferior extremities in 41 patients with multiple sclerosis in a 10-week intervention period.

## 1.3. MATERIAL AND METHODS

41 multiple sclerosis patients with mild to moderate disability (Kurtzke Expanded Disability Status Scale 1.5 to 6.5) were allocated either to an intervention group or to the control group .

At the beginning of the study the patients underwent several test (pre-test) for strength using a Biodex System 3 dynamometer (which register measures of isokinetic, isotonic, isometric variables) and test for coordination (using a technique described in Meesen R. et al ,2002) .

Then, patients were divided into 5 groups. The strength group undergoes a traditional strength training program for the arms and legs (alternating 2,3 times a week during 10 weeks).

The strength plus electrostimulation group receives a traditional strength program for the arms and legs in combination with electrostimulation ((alternating 2,3 times a week during 10 weeks).

The whole body vibration group receives a traditional strength training program for the arms and whole body vibration exercises for the legs (alternating 2, 3 times a week during 10 weeks)

The micro electrostimulation group receives micro electro stimulation at home ( 5 times a week during 10 weeks).

The control group was advised to avoid any great change in their physical activity habits during the next 10 weeks.

After 10 weeks the patients underwent all of the test again.

## 2. DATA DESCRIPTION

### 2.1. PATIENT SELECTION AND TREATMENT GROUP CONFORMATION

The study included 41 patients multiple sclerosis female and male, with mild to moderate disability (Kurtzke's expanded disability status scale 1.5-6.5) (Rehabilitation Assesment Measures in Multiple Sclerosis. 2003).

The patients were allocated in five therapeutical groups . The patient selection to each group was done using the following method:

The 43 patients were ranked according to the EDSS SCALE in three groups: Group 1, patients with EDSS score between 1,5 to 3; group 2, patients with EDSS score between 3 to 4,5; group 3, patients with EDSS score between 4,5 to 6. Finally, each group was randomly sampled taking three or four individual to conform each of the five treatment groups . The main characteristics for the patients involved in the study are shown in table 1.

Table 1 Patient Characteristics in the study

| | **Control** | **Resistance** | **Resistance Electric Stimulation** | **Whole Body Vibration** | **Micro Current Stimulation** |
|---|---|---|---|---|---|
| **Number of Patients** | 8 | 9 | 8 | 8 | 8 |
| **Age (Years)** | | | | | |
| Mean | 47.25 | 42.7 | 48.75 | 44.37 | 46.5 |
| Std Dev | 7.12 | 11.05 | 9.49 | 7.45 | 11.36 |
| Min | 39 | 24 | 38 | 35 | 25 |
| Max | 56 | 60 | 66 | 55 | 58 |
| **Sex** | | | | | |
| Male | 2 | 4 | 3 | 3 | 0 |
| Female | 6 | 4 | 5 | 5 | 8 |
| **Type of Multiple Sclerosis** | | | | | |
| 1 | 4 | 4 | 2 | 3 | 3 |
| 2 | 3 | 3 | 2 | 4 | 2 |
| 3 | 1 | 2 | 4 | 1 | 3 |
| **EDSS** | | | | | |
| Mean | 4.25 | 4.38 | 4.5 | 4.68 | 4.25 |
| Std Dev | 1.16 | 1.36 | 1.03 | 1.65 | 1.33 |
| Min | 3 | 2 | 3 | 1.5 | 2 |
| Max | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 |

## 2.2. INDEPENDENT VARIABLES

The different treatment considered are presented in table 2.

Table 2 Independent variables (Treatment groups)

| GROUP | NAME | DESCRIPTION |
|---|---|---|
| 1 | STRENGTH | This group undergoes a traditional strength training program for the arms and legs (alternating 2,3 times a week during 10 weeks) |
| 2 | STRENGTH PLUS ELECTROSTIMULATION | This group receives a traditional strength program for the arms and legs in combination with electrostimulation (alternating 2,3 times a week during 10 weeks) |
| 3 | WHOLE BODY VIBRATION | This group receives a traditional strength training program for the arms and whole body vibration exercises for the legs (alternating 2,3 times a week during 10 weeks) |
| 4 | MICRO ELECTRO STIMULATION | This group receives micro electro stimulation at home (5 times a week during 10 weeks) |
| 5 | CONTROL | This group was advised to avoid any great change in their physical activity habits during the next 10 weeks |

## 2.3. DEPENDENT VARIABLES

### 2.3.1 GENERAL OVERVIEW OF THE DEPENDENT VARIABLES.

Each of the variables were recorded for each of the patients beginning the therapeutical intervention (preintervention) and finalizing (10 weeks after) the therapeutical intervention (postintervention) .

The variables analyzed in this study corresponded to the **difference** between post intervention and preintervention for each of the variables recorded.

### 2.3.2. STRENGTH EVALUATION VARIABLES

The strength variables are displayed in Table .3

Table 3 Strength evaluation variables.

| ID | VARIABLE | DESCRIPTION | UNIT | VARIABLE TYPE |
|---|---|---|---|---|
| 1 | ISOM90rQ | Isometric test at 90° angle of the right knee of Quadriceps - Peak torque | (Nm) | Continuous |
| 2 | ISOM90rH | Isometric test at 90° angle of the rigth knee of the Hamstring - Peak torque | (Nm) | Continuous |
| 3 | ISOM45rQ: | Isometric test at 45° angle of the Right knee of the Quadriceps (=muscle) - Peak torque | (Nm) | Continuous |
| 4 | ISOM45rH | Isometric test at 45° angle of the Right knee of the Hamstring - Peak torque | (Nm) | Continuous |
| 5 | ISOM90lQ | Isometric test at 90° angle of the Left knee of the Quadriceps - Peak torque | (Nm) | Continuous |
| 6 | ISOM90lH: | Isometric test at 90° angle of the Left knee of the Hamstring - Peak torque | (Nm) | Continuous |
| 7 | ISOM45lQ | Isometric test at 45° angle of the left knee of the Quadriceps (=muscle) - Peak torque | (Nm) | Continuous |
| 8 | ISOM45lH | Isometric test at 45° angle of the Left knee of the Hamstring (=muscle) - Peak torque | (Nm) | Continuous |
| 9 | ISOTr1%Pv: | Isotonic test of 1% of the maximal strength of the Right knee - Peak Velocity | (Deg/Sec) | Continuous |
| 13 | ISOTr20%PV | Isotonic test of 20% of the maximal strength of the Right knee - Peak Velocity | (Deg/Sec) | Continuous |
| 17 | ISOTr40%PV | Isotonic test of 40% of the maximal strength of the Right knee – Peak Velocity | (Deg/Sec) | Continuous |
| 21 | ISOTr60%PV | Isotonic test of 40% of the maximal strength of the Right knee – Peak Velocity | (Deg/Sec) | Continuous |
| 25 | ISOTl1%Pv: | Isotonic test of 1% of the maximal strength of the left knee - Peak Velocity | (Deg/Sec) | Continuous |
| 29 | ISOTl20%PV | Isotonic test of 20% of the maximal strength of the left knee - Peak Velocity | (Deg/Sec) | Continuous |
| 33 | ISOTl40%PV | Isotonic test of 40% of the | (Deg/Sec) | Continuous |

| | | | | |
|---|---|---|---|---|
| | | maximal strength of the left knee – Peak Velocity | | |
| 37 | ISOTI60%PV | Isotonic test of 40% of the maximal strength of the left knee – Peak Velocity | (Deg/Sec) | Continuous |
| 41 | ISOKr60PT: | Isokinetic test of the Right knee at 60°/Sec – Peak Torque | (Nm) | Continuous |
| 46 | ISOKr180PT: | Isokinetic test of the Right knee at 180°/Sec - Peak Torque | (Nm) | Continuous |
| 50 | ISOKr240PT: | Isokinetic test of the Right knee at 240°/Sec - Peak Torque | (Nm) | Continuous |
| 54 | ISOKl60PT: | Isokinetic test of the left knee at 60°/Sec – Peak Torque | (Nm) | Continuous |
| 58 | ISOKl180PT: | Isokinetic test of the left knee at 180°/Sec - Peak Torque | (Nm) | Continuous |
| 62 | ISOKl240PT: | Isokinetic test of the Left knee at 240°/Sec - Peak Torque | (Nm) | Continuous |

### 2.3.3. COORDINATION EVALUATION VARIABLES

The Coordination evaluation is a set of test (Table 4) which measure the coordination of leg movements evaluated in phase and in antiphase movements.

Table 4 Coordination evaluation variables.

| VARIABLE | DESCRIPTION | UNIT | TYPE |
|---|---|---|---|
| ACCURACY IN PHASE | Evaluation of the accuracy of leg movements in phase at different frequencies (75, 100, 125, 150 MHZ) | Degree | Continuous Quantitative |
| ACCURACY IN ANTI – PHASE | Evaluation of the accuracy of leg movements in phase at different frequencies (75, 100, 125, 150 MHZ) | Degree | Continuous Quantitative |
| STABILITY IN PHASE | Evaluation of the stability of leg movements in phase at different frequencies (75, 100, 125, 150 MHZ) | Degree | Continuous Quantitative |
| STABILITY IN ANTI – PHASE | Evaluation of the stability of leg movements in phase at different frequencies (75, 100, 125, 150 MHZ) | Degree | Continuous Quantitative |

## 3. METHODOLOGY

### 3.1. INTRODUCTION

Repeated measures refers to data sets with multiple measurements of a response variable on the same experimental unit. In most application, the multiple measurements are made over a period of time.(Litell et al, 2006) or other experimental or observational conditions , and are often referred to as within-subject factors. (West et al , 2007)

In a general sense, any data that are measured repeatedly over time or space are repeated measures data.

### 3.2. BASIC CONCEPTS OF REPEATED MEASURES

"A commonly occurring repeated measures study of completely randomized experimental design with data collected in a sequence of equally spaced time points from each experimental unit. In the basic setup of a completely randomized design with repeated measures, there are two factors, treatments and time. In this sense, all repeated measures experiments are factorial experiments. Treatment is called the between – subjects factor because levels of treatment can change only between subjects; all measurements on the same subject will represent the same. Time is called a within – subjects factor because different measurements on the same how treatment means differ, (2) how treatment means change over time, and (3) how differences between treatment means change over time.In other words, is there a treatment main effect, is there a time main effect, and is there a treatment-by-time interaction". (Litell et al, 2006)

For the analysis of the dataset were applied mixed methods with special parametric structure on the covariance matrices.

Mixed model analysis involves two stages: first, estimate the covariance structure. Second, asses treatment and time effects using generalized least squares with the estimated covariance. (Littell et al 2000) break these stages further into a four step procedure for mixed model analyisis:

Step1: Model the mean structure, usually by specification of the fixed effects.

Step 2: Specify the covariance structure, between subjects as well as within subjects.
Step 3: Fit the model accounting for the covariance structure.
Step 4: Make statistical inference based on the results of step3.

### 3.3. STATISTICAL MODELLING

A statistical model for repeated measures data is

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

Where

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at time *k*, containing effects for treatment, time, and treatment x time interaction

$e_{ijk}$ is the random error associated with the measurement at time k on the jth subject that is assigned to treatment i. It is assumed that errors for different subjects are independent, giving

Cov[$e_{ijk}$,$e_{i'j'l}$]=0 if either $i \neq i'$ or $j \neq j'$

Also , since measurement on the same subject are over a time course, they may have different variances, and correlations between pairs of measurements may depend on the length of the time interval between the measurements. In the most general setting the assumption is

$Var[e_{ijk}] = \sigma_k^2$ and $Var[e_{ijk}, e_{eijk'}] = \sigma_{kk'}$

### 3.4. RESIDUAL DIAGNOSTICS FOR REPEATED MEASURES

"Informal techniques are commonly used to check residual diagnostics; these technique rely on the human mind and eye, and are used to decide whether or not a specific pattern exists in the residuals. In the context of the standard linear model, the simples example us to decide whether a given set of residuals plotted against predicted values represents a random pattern or not. These residuals versus fitted values plots are used to verify model assumptions and to detect outliers and potentially influential observations" (Welsh et al , 2007)

**3. 5. APPLICATION TO THE DATASET**

The dataset analysis was done adapting repeated measures methodology. The factor time in a repeated measures setting was replaced by a set of variables with similar characteristics measured in each subject.

For the coordination variables werecreated the following groups:

Group Stability in Phase , this group consist of the variables registering stability in phase at the differet frequencies, 75 MHz, 100Mhz, 125 MHz and 150 Mhz.

Group Stability in Antiphase , this group consist of the variables registering stability in antiphase at different frequencies, 75 MHz, 100Mhz, 125 MHz and 150 Mhz.

Group Accuracy in Phase , this group consist of the variables registering accuracy in phase at different frequencies, 75 MHz, 100Mhz, 125 MHz and 150 Mhz.

Group Accuracy in Antiphase , this group consist of the variables registering accuracy in antiphase at different frequencies, 75 MHz, 100Mhz, 125 MHz and 150 Mhz.

For the analysis of the groups Stability in Phase, Stability in Antiphase, Accuracy in Phase and Accuracy in Antiphase the independent variables analyzed correspond only to the following: control, resistance plus electrostimulation, resistance and whole body vibration.

For the resistance/strength group the following groups of analysis were created:

Group Isokinetic Peak torque right leg, this group consist of the variables recording isokinetic peak torque at 60 Degrees, 180 degrees and 240 degrees in the right leg.

Group Isokinetic Peak torque left leg, this group consist of the variables recording isokinetic peak torque at 60 Degrees, 180 degrees and 240 degrees in the left leg.

Group Isotonic Peak torque Right Leg, this group consist of the variables

recording isotonic peak velocity at 1%, 20%, 40% and 60% in the right leg.
Group Isotonic Peak velocity Left Leg, this group consist of the variables recording isotonic peak torque at 1%, 20%, 40% and 60% in the left leg.
Group Isometric Peak torque Right Leg, this group consist of the variables recording isometric peak torque at 45 degrees and 90 degrees in the Hamstring and 45 degrees and 90 degrees in the Quadriceps in the right leg.
Group Isometric Peak torque Left Leg, this group consist of the variables recording isometric peak torque at 45 degrees and 90 degrees in the Hamstring and 45 degrees and 90 degrees in the Quadriceps in the left leg.
For the analysis of the groups Isokinetic Peak torque right leg, Isokinetic Peak torque left leg, Isotonic Peak torque Right Leg, Isotonic Peak velocity Left Leg, Isometric Peak torque Right Leg, and Isometric Peak torque Left Leg the independent variables analyzed correspond only to the following: control, resistance plus electrostimulation, resistance, microelectrostimulation and whole body vibration.

**3.6. DATA MODELING**

For each group of variables the model used is presented

**3.6.1. Model For Group Stability In Phase**

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at variable stability in phase at different frequencies *k* containing effects for treatment, stability in phase variable at different frequencies , and the interaction between the frequency level and treatment .

$e_{ijk}$ is the random error associated with the measurement at stability in phase variable *k* on the *j*th subject that is assigned to treatment *i*.

**3.6.2. Model For Group Stability In Antiphase Group**

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at stability in anti phase variable at different frequencies *k*, containing effects for treatment, stability in antiphase variable at different frequencies , and treatment by stability in antiphase variable at different frequencies interaction.

$e_{ijk}$ is the random error associated with the measurement at stability in antiphase variable *k* on the *j*th subject that is assigned to treatment *i*.

**3.6.3. Model For Accuracy In Phase**

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at variable accuracy in phase at different frequencies *k*, containing effects for treatment, accuracy in phase variable at different frequencies , and treatment by accuracy in phase variable at different frequencies interaction.

$e_{ijk}$ is the random error associated with the measurement at accuracy in phase variable *k* on the *j*th subject that is assigned to treatment *i*.

**3.6.4. Model For Accuracy In Antiphase**

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at accuracy in anti phase at different frequencies *k*, containing effects for treatment, accuracy in antiphase at different frequencies , and treatment by accuracy in antiphase variable at different frequencies interaction.

$e_{ijk}$ is the random error associated with the measurement at accuracy in antiphase variable *k* on the *j*th subject that is assigned to treatment *i*.

**3.6.5. Model for Group Isokinetic Peak Velocity Right Leg,**

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at isokinetic peak velocity in right leg at different degrees *k*, containing effects for treatment, isokinetic peak velocity in right leg at different degrees , and treatment by isokinetic peak velocity in right leg at different degrees interaction.

$e_{ijk}$ is the random error associated with the measurement at isokinetic peak velocity in right leg *k* on the *j*th subject that is assigned to treatment *i*.

**3.6.6. Model For Group Isokinetic Peak Velocity Left Leg**

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at isokinetic peak velocity in left leg at different degrees *k*, containing effects for treatment, isokinetic peak velocity in left leg at different degrees , and treatment by isokinetic peak velocity in left leg at different degrees interaction.

$e_{ijk}$ is the random error associated with the measurement at isokinetic peak velocity in left leg *k* on the *j*th subject that is assigned to treatment *i*.

**3.6.7. Model For Group Isotonic Peak Torque Right Leg**

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at isotonic peak torque in right leg at different percentage *k*, containing effects for treatment, isotonic peak torque in right leg at different percentage , and treatment by isotonic peak torque in right leg at different percentage interaction.

$e_{ijk}$ is the random error associated with the measurement at isotonic peak torque in right leg *k* on the *j*th subject that is assigned to treatment *i*.

**3.6.8. Model For Group Isotonic Peak Torque Left Leg,**

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at isotonic peak torque in Left leg at different percentage *k*, containing effects for treatment, isotonic peak torque in Left leg at different percentage , and treatment by isotonic peak torque in Left leg at different percentage interaction.

$e_{ijk}$ is the random error associated with the measurement at isotonic peak torque in Left leg *k* on the *j*th subject that is assigned to treatment *i*.

**3.6.9. Model For Group Isometric Peak Torque Right Leg,**

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at isometric peak torque in Right leg at different degree and position *k*, containing effects for treatment, isometric peak torque in Right leg at different degree and position , and treatment by isometric peak torque in Right leg at different degree and position interaction.

$e_{ijk}$ is the random error associated with the measurement at isometric peak torque in Right leg *k* on the *j*th subject that is assigned to treatment *i*.

**3.6.10. Model For Group Isometric Peak Torque Left Leg**

$$Y_{ijk} = \mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik} + e_{ijk}$$

$\mu + \alpha_i + \gamma_k + (\alpha\gamma)_{ik}$ is the mean for treatment *i* at isometric peak torque in Left leg at different degree and position *k*, containing effects for treatment, isometric peak torque in Left leg at different degree and position , and treatment by isometric peak torque in Left leg at different degree and position interaction.

$e_{ijk}$ is the random error associated with the measurement at isometric peak torque in Right leg *k* on the *j*th subject that is assigned to treatment *i*.

# 4. RESULTS

## 4.1 EXPLORATORY DATA ANALYSIS

### 4.1.1. MEAN STRUCTURE PER GROUP OF VARIABLES

#### 4.1.1.1. Group Stability in Phase

The mean for the outcome (degree) profile for present a peak in the outcome at the frequency 125 MHz and the mean profiles remain constant until the 125 MHz frequency and in the 150 MHz present different behavior (Appendix Figure 7.1.)

#### 4.1.1.2. Group Stability in Antiphase

The mean profile for the outcome (degree) present a peak at the frequency 100 MHz and the profiles by treatment not show any particular trend between the first and the last frequency. (Appendix Figure 7.2.)

#### 4.1.1.3. Group Accuracy in phase

The mean profile for the outcome (degree) present a peak at the frequency 100MHz, and the profiles by treatment for control, resistance and whole body vibration present the same behavior through the different frequencies and the resistance plus electroestimulation decreases through the frequencies. (Appendix Figure 7.3.)

#### 4.1.1.4. Group Accuracy in antiphase

The mean profile for the outcome (degree) present a peak at the frequency 100MHz, and the profiles by treatment for control and whole body vibration increases slightly and the resistance plus electroestimulation and resistance decreases through the frequencies. (Appendix Figure 7.4.)

#### 4.1.1.5. Group Isokinetic Peak Torque right leg

The mean profile for the outcome (Torque in Newton metre) present a lower peak at 180 degrees, and the profiles by treatment for micro electro stimulation, resistance plus electroestimulation, resistance and whole body vibration remain without change through the different degrees and the control increases through the frequencies (Appendix Figure 7.5.)

#### 4.1.1.6. Group Isokinetic Peak Torque left leg

The mean  profile for the outcome (Torque in Newton metre) present an upper peak at 180 degrees, and the profiles by treatment have the same behavior through the different degrees(Appendix Figure 7.6.)

**4.1.1.7. Group Isotonic Peak Velocity right leg**

The mean  profile for the outcome (Peak Velocity in Degree/second) present an two upper peak at 1 and 60 percentage,   and the profiles by treatment  doesn't change through the different percentage (Appendix Figure 7.7.)

**4.1.1.8. Group Isotonic Peak Velocity Left leg**

The mean  profile for the outcome (Peak Velocity in Degree/second) present an increasing trend  and the profiles by treatment  increases slightly through the percentages (Appendix Figure 7.8.)

**4.1.1.9. Group Isometric Peak torque Right Leg**

The mean  profile for the outcome (Torque in Newton metre)  present an increasing trend with a peak in the ISOM45RQ variable and the profiles by treatment  increases slightly through the different variables (Appendix Figure 7.9.)

**4.1.1.10. Group Isometric Peak torque Left Leg**

The mean  profile for the outcome (Torque in Newton metre)  present an increasing trend with a peak in the ISOM90RQ variable and the profiles by treatment show the treatment whole body vibration increases slightly through the different variables (Appendix Figure 7.10.)

**4..1.2. VARIANCE STRUCTURE PER GROUP OF VARIABLES**

**4..1.2.1. Group Stability in Phase**

The variance profile for the outcome (degree)  present a  upper peaks in the outcome at the frequencies  100 and 150 MHz and the variance profiles by treatment   appear slightly constant in each frequency (Appendix Figure 7.11.)

**4..1.2.2. Group Stability in Anti Phase**

The variance profile for the outcome (degree)  present a decreasing trend through the variables  and the variance profiles by treatment  show  a decreasing trend between with constant variance in each frequency. (Appendix Figure 7.12.)

**4.1.2.3. Group Accuracy in phase**

The variance profile for the outcome (degree) present two upper peaks at 100 and 150 MHz and the variance profiles by treatment show not change through the frequencies with the exception of resistance which present a peak at the frequency 100. (Appendix Figure 7.13.)

**4.1.2.4. Group Accuracy in antiphase**

The variance profile for the outcome (degree) present a decreasing trend through the variables and the variance profiles by treatment show a decreasing trend between with constant variance in each frequency. (Appendix Figure 7.14.)

**4.1.2.5. Group Isokinetic Peak Torque right leg**

The variance profile for the outcome (Torque in Newton metre) present a lower peak at 180 degrees, and the variance profiles by treatment for micro electro stimulation, resistance plus electroestimulation, resistance and whole body vibration show a decreasing pattern through the different degrees and the control increases through the frequencies (Appendix Figure 7.15.)

**4.1.2.6. Group Isokinetic Peak Torque left leg**

The variance profile for the outcome (Torque in Newton metre) present an upper peak at 180 degrees, and the profiles by treatment show a decreasing pattern through the different degrees (Appendix Figure 7.16.)

**4.1.2.7. Group Isotonic Peak Velocity right leg**

The variance profile for the outcome (Peak Velocity in Degree/second) present a lower peak at 40 percentage, and the profiles by treatment show a slight decreasing pattern through the different percentage (Appendix Figure 7.17.)

**4.1.2.8. Group Isotonic Peak Velocity Left leg**

The variance profile for the outcome (Peak Velocity in Degree/second) present an upper peak at 40 percentage and the profiles by treatment increases for the control and the rest of the treatment show a decreasing trend (Appendix Figure 7.18.)

**4.1.2.9. Group Isometric Peak Torque Right Leg**

The variance profile for the outcome (Torque in Newton metre) present an increasing trend with a peak in the ISOM45RQ variable and the profiles by treatment show the variance are closer in the ISOM90RH variable and spread at the ISOM45RQ variable (Appendix Figure 7.19.)

**4.1.2.10. Group Isometric Peak Torque Left Leg**

The variance profile for the outcome (Torque in Newton metre) present an increasing trend with a peak in the ISOM45LQ variable and the profiles by treatment show the treatments whole body vibration and control present higher variances in the ISOM90LH and ISOM45RQ variables (Appendix Figure 7.20.)

**4..1.3. CORRELATION STRUCTURE PER GROUP OF VARIABLES**

**4..1.3.1. Group Stability in Phase**

The pearson correlation coefficients shows the correlation between the variables are different. ( Appendix Table 7.1.)

**4..1.3.2. Group Stability in Anti Phase**

The pearson correlation coefficients shows the correlation between the variables Stability in phase at 75, 100 and 125 MHz are closer but not with the 150 MHz frequency. ( Appendix Table 7.2.)

**4.1.3.3. Group Accuracy in phase**

The pearson correlation coefficients shows the correlation between the variables are different. ( Appendix Table 7.3.)

**4.1.3.4. Group Accuracy in antiphase**

The pearson correlation coefficients shows the correlation between the variables are different. ( Appendix Table 7.4.)

**4.1.3.5. Group Isokinetic Peak Torque right leg**

The pearson correlation coefficients shows the correlation between the variables Isokinetic Peak Torque at 60, 180 and 240 degrees are closer. ( Appendix Table 7.5.)

**4.1.3.6. Group Isokinetic Peak Torque left leg**

The pearson correlation coefficients shows the correlation between the variables Isokinetic Peak Torque at 60, 180 and 240 degrees are closer. ( Appendix Table 7.6.)

**4.1.3.7. Group Isotonic Peak Velocity right leg,**

The pearson correlation coefficients shows the correlation between the variables are different. ( Appendix Table 7.7.)

**4.1.3.8. Group Isotonic Peak Velocity Left leg,**

The pearson correlation coefficients shows the correlation between the variables are different. ( Appendix Table 7.8.)

**4.1.3.9. Group Isometric Peak Torque Right Leg,**

The pearson correlation coefficients shows the correlation between the variable ISOM90RH and ISOM90RQ are closer than the other variables. ( Appendix Table 7.9.)

**4.1.3.10. Group Isometric Peak Torque Left Leg,**

The pearson correlation coefficients shows the correlation between the different variables are closer. ( Appendix Table 7.10.)

## 4.2. SELECTION OF COVARIANCE STRUCTURE

Based in the analysis of the exploratory Data analysis and in the fit statistics for the proposed model for each group of variables the covariace structure was selected. For each group are presented the fit statistics and the covariance structure selected.

### 4..2.1. Group Stability in Phase

Table 5 Information Criteria Stability in Phase

| | Compound Simmetry | Unstructured |
|---|---|---|
| -2 Res Log Likelihood | 723.7 | 636.1 |
| AIC (smaller is better) | 727.7 | 656.1 |
| AICC (smaller is better) | 727.8 | 658.2 |
| BIC (smaller is better) | 730.7 | 671.0 |

A likelihood ratio test for compound symmetry compared to unstructured is:

| | -2 Res Log Likelihood |
|---|---|
| Compound Symmetry | 723.7 |
| Unstructured | 636.1 |
| | 87.6, 8 degrees of freedom (p<0.0005) |

The selected covariance structure is unstructured.

### 4.2.2. Group Stability in antiphase

Table 6 Information Criteria Stability in Anti Phase

| | Compound Simmetry | Unstructured |
|---|---|---|
| -2 Res Log Likelihood | 827.9 | 760.4 |
| AIC (smaller is better) | 831.9 | 780.4 |
| AICC (smaller is better) | 832.0 | 782.5 |
| BIC (smaller is better) | 834.9 | 795.3 |

A likelihood ratio test for compound symmetry compared to unstructured is:

| | -2 Res Log Likelihood |
|---|---|
| Compound Symmetry | 827.9 |
| Unstructured | 760.4 |
| | 67.5, 8 degrees of freedom (p<0.005) |

The selected covariance structure selected is unstructured.

**4.2.3. Group Accuracy in phase**

Table 7 Information Criteria Accuracy in Phase

| | Compound Simmetry | Unstructured |
|---|---|---|
| -2 Res Log Likelihood | 618.7 | 593.4 |
| AIC (smaller is better) | 622.7 | 613.4 |
| AICC (smaller is better) | 622.8 | 615.5 |
| BIC (smaller is better) | 625.7 | 628.4 |

A likelihood ratio test for compound symmetry compared to unstructured is:

| | -2 Res Log Likelihood |
|---|---|
| Compound Symmetry | 618.7 |
| Unstructured | 593.4 |
| | 25.3 , 8 degrees of freedom (p<0.005) |

The selected covariance structure is unstructured.

**4.2.4. Group Accuracy in antiphase**

Table 8 Information Criteria Accuracy in Anti Phase (REML)

| | Compound Symmetry | Unstructured |
|---|---|---|
| -2 Res Log Likelihood | 743.5 | 691.7 |
| AIC (smaller is better) | 747.5 | 711.7 |
| AICC (smaller is better) | 747.6 | 713.8 |
| BIC (smaller is better) | 750.4 | 726.7 |

A likelihood ratio test for compound symmetry compared to unstructured is:

| | -2 Res Log Likelihood |
|---|---|
| Compound Symmetry | 743.5 |
| Unstructured | 691.7 |
| | 51.8 , 8 degrees of freedom (p<0.0005) |

The covariance structure selected is unstructured.

**4.2.5. Group Isokinetic Peak Torque right leg,**

Table 9 Information Criteria Isokinetic Right leg Peak Torque

| FIT STATISTICS | COMPOUND SIMMETRY | UNSTRUCTURED |
|---|---|---|
| -2 Res Log Likelihood | 871.5 | 854.1 |
| AIC (smaller is better) | 875.5 | 866.1 |
| AICC (smaller is better) | 875.6 | 866.9 |
| BIC (smaller is better) | 878.9 | 876.4 |

A likelihood ratio test for compound symmetry compared to unstructured is:

| | -2 Res Log Likelihood |
|---|---|
| Compound Symmetry | 871.5 |
| Unstructured | 854.1 |
| | 17.4, 8 degrees of freedom (p<0.05) |

The selected covariance structure is unstructured.

#### 4.2.6. Group Isokinetic Peak Torque left leg,

Table 10 Information Criteria Isokinetic Right leg Peak Torque

| FIT STATISTICS | COMPOUND SIMMETRY | UNSTRUCTURED |
|---|---|---|
| -2 Res Log Likelihood | 862.5 | 851.6 |
| AIC (smaller is better) | 866.5 | 863.6 |
| AICC (smaller is better) | 866.7 | 864.5 |
| BIC (smaller is better) | 870.0 | 873.9 |

A likelihood ratio test for compound symmetry compared to unstructured is:

| | -2 Res Log Likelihood |
|---|---|
| Compound Symmetry | 862.5 |
| Unstructured | 851.6 |
| | 10.9, 8 degrees of freedom (p<0.5) |

The selected covariance structure is compound simmetry.

#### 4.2.7. Group Isotonic Peak Velocity right leg,

Table 11 Information Criteria Isotonic Right leg Peak Velocity

| FIT STATISTICS | COMPOUND SIMMETRY | UNSTRUCTURED |
|---|---|---|
| -2 Res Log Likelihood | 1423.2 | 1378.6 |
| AIC (smaller is better) | 1427.2 | 1398.6 |
| AICC (smaller is better) | 1427.3 | 1400.2 |
| BIC (smaller is better) | 1430.7 | 1415.7 |

A likelihood ratio test for compound symmetry compared to unstructured is:

| | -2 Res Log Likelihood |
|---|---|
| Compound Symmetry | 1423.2 |
| Unstructured | 1378.6 |
| | 44.6, 8 degrees of freedom (p<0.005) |

The selected covariance structure is unstructured.

#### 4.2.8. Group Isotonic Peak Velocity Left leg,

Table 12 Information Criteria Isotonic Left leg Peak Velocity

| FIT STATISTICS | COMPOUND SIMMETRY | UNSTRUCTURE |
|---|---|---|
| -2 Res Log Likelihood | 1442.8 | 1395.8 |
| AIC (smaller is better) | 1446.8 | 1415.8 |
| AICC (smaller is better) | 1446.8 | 1417.5 |
| BIC (smaller is better) | 1450.2 | 1433.0 |

A likelihood ratio test for compound symmetry compared to unstructured is:

| | -2 Res Log Likelihood |
|---|---|
| Compound Symmetry | 1442.8 |
| Unstructured | 1395.8 |
| | 47, 8 degrees of freedom (p<0.005) |

The selected covariance structure is unstructured.

### 4.2.9. Group Isometric Peak torque Right Leg,

Table 13 Information Criteria Isometric Right leg Peak Torque

| FIT STATISTICS | COMPOUND SIMMETRY | UNSTRUCTURED |
|---|---|---|
| -2 Res Log Likelihood | 1083.4 | 1055.8 |
| AIC (smaller is better) | 1087.4 | 1075.8 |
| AICC (smaller is better) | 1087.4 | 1077.5 |
| BIC (smaller is better) | 1090.7 | 1092.7 |

A likelihood ratio test for compound symmetry compared to unstructured is:

| | -2 Res Log Likelihood |
|---|---|
| Compound Symmetry | 1083.4 |
| Unstructured | 1055.8 |
| | 27.6, 8 degrees of freedom (p<0.005) |

The selected covariance structure is unstructured.

### 4.2.10. Group Isometric Peak torque Left Leg,

Table 14 Information Criteria Isometric Left leg Peak Torque (REML)

| FIT STATISTICS | COMPOUND SIMMETRY | UNSTRUCTURED |
|---|---|---|
| -2 Res Log Likelihood | 1224.8 | 1139.3 |
| AIC (smaller is better) | 1228.8 | 1159.3 |
| AICC (smaller is better) | 1228.9 | 1161.0 |
| BIC (smaller is better) | 1232.2 | 1176.2 |

A likelihood ratio test for compound symmetry compared to unstructured is:

| | -2 Res Log Likelihood |
|---|---|
| Compound Symmetry | 1224.8 |
| Unstructured | 1139.3 |
| | 85.5, 8 degrees of freedom (p<0.0005) |

The selected covariance structure is unstructured.

## 4.3. TEST OF FIXED EFFECTS

The test of fixed effects provides Chi Square Statistics and F statistics based on Generalized Least Squares for testing the statistical significance of the treatment, the variable at each different level and the treatment by variable interaction.

### 4..3.1. Group Stability in Phase

Table 15 Test of Fixed Effects Stability in Phase (Method REML)

| Effect | Num DF | Den DF | Chi-Square | F Value | Pr > ChiSq | Pr > F |
|---|---|---|---|---|---|---|
| TREATMENT | 3 | 29 | 1.14 | 0.38 | 0.7666 | 0.7673 |
| FREQUENCY | 3 | 29 | 4.33 | 1.44 | 0.2277 | 0.2502 |
| TREATMENT * FREQUENCY | 9 | 29 | 10.69 | 1.19 | 0.2978 | 0.3396 |

The test of fixed effects show no significant differences at any of the factors under evaluation in the Stability in Phase group

### 4.3.2. Group Stability in antiphase

Table 16 Test of Fixed Effects Stability in Anti Phase (Method REML)

| Effect | Num DF | Den DF | Chi-Square | F Value | Pr > ChiSq | Pr > F |
|---|---|---|---|---|---|---|
| TREATMENT | 3 | 29 | 1.98 | 0.66 | 0.5764 | 0.5832 |
| FREQUENCY | 3 | 29 | 7.23 | 2.41 | 0.0648 | 0.0871 |
| TREATMENT * FREQUENCY | 9 | 29 | 10.30 | 1.14 | 0.3270 | 0.3654 |

The test of fixed effects show no significant differences at any of the factors under evaluation in the Stability in Anti Phase group

### 4.3.3. Group Accuracy in Phase

Table 17 Test of Fixed Effects Accuracy in Phase (Method REML) Covariance Structure (Unstructured)

| Effect | Num DF | Den DF | Chi-Square | F Value | Pr > ChiSq | Pr > F |
|---|---|---|---|---|---|---|
| TREATMENT | 3 | 29 | 2.74 | 0.91 | 0.4334 | 0.4466 |
| FREQUENCY | 3 | 29 | 1.57 | 0.52 | 0.6673 | 0.6707 |
| TREATMENT * FREQUENCY | 9 | 29 | 9.98 | 1.11 | 0.3521 | 0.3875 |

The test of fixed effects show no significant differences at any of the factors under evaluation in the Accuracy in Phase group

### 4.3.4. Group Accuracy in antiphase

Table 18 Test of Fixed Effects Accuracy in Anti Phase (Method REML)

| Effect | Num DF | Den DF | Chi-Square | F Value | Pr > ChiSq | Pr > F |
|---|---|---|---|---|---|---|
| TREATMENT | 3 | 29 | 2.64 | 0.88 | 0.4498 | 0.4622 |
| FREQUENCY | 3 | 29 | 4.85 | 1.62 | 0.1832 | 0.2071 |
| TREATMENT * FREQUENCY | 9 | 29 | 11.94 | 1.33 | 0.2165 | 0.2662 |

The test of fixed effects show no significant differences at any of the factors under evaluation in the Accuracy in Anti Phase group

### 4.3.5. Group Isokinetic Peak Torque Right Leg

Table 19 Test of Fixed Effects Isokinetic Right leg Peak Torque (Method REML)

| Effect | Num DF | Den DF | Chi-Square | F Value | Pr > ChiSq | Pr > F |
|---|---|---|---|---|---|---|
| TREATMENT | 4 | 36 | 6.19 | 1.55 | 0.1852 | 0.2092 |
| DEGREE | 2 | 36 | 0.15 | 0.08 | 0.9271 | 0.9272 |
| TREATMENT * DEGREE | 8 | 36 | 11.32 | 1.42 | 0.1842 | 0.2237 |

The test of fixed effects show no significant differences at any of the factors under evaluation in the Isokinetic Peak Torque Right Leg group.

### 4.3.6. Group Isokinetic Peak Torque left leg

Table 20 Test of Fixed Effects Isokinetic Right leg Peak Torque (Method REML)

| Effect | Num DF | Den DF | Chi-Square | F Value | Pr > ChiSq | Pr > F |
|---|---|---|---|---|---|---|
| TREATMENT | 4 | 36 | 1.89 | 0.47 | 0.7561 | 0.7557 |
| DEGREE | 2 | 36 | 0.03 | 0.01 | 0.9870 | 0.9870 |
| TREATMENT * DEGREE | 8 | 36 | 8.69 | 1.09 | 0.3693 | 0.3949 |

The test of fixed effects show no significant differences at any of the factors under evaluation in the Isokinetic Peak Torque Left Leg group.

### 4.3.7. Group Isotonic Peak Velocity right leg

Table 21 Test of Fixed Effects Isotonic Left leg Peak Velocity (Method REML)

| Effect | Num DF | Den DF | Chi-Square | F Value | Pr > ChiSq | Pr > F |
|---|---|---|---|---|---|---|
| TREATMENT | 4 | 36 | 3.73 | 0.93 | 0.4435 | 0.4559 |
| PERCENTAGE | 3 | 36 | 3.43 | 1.14 | 0.3298 | 0.3446 |
| TREATMENT * PERCENTAGE | 12 | 36 | 14.08 | 1.17 | 0.2955 | 0.3377 |

The test of fixed effects show no significant differences at any of the factors under evaluation in the Isotonic Peak Velocity Right Leg group.

### 4.3.8. Group Isotonic Peak Velocity Left leg,

Table 22 Test of Fixed Effects Isotonic Left leg Peak Velocity (Method REML)

| Effect | Num DF | Den DF | Chi-Square | F Value | Pr > ChiSq | Pr > F |
|---|---|---|---|---|---|---|
| TREATMENT | 4 | 35 | 2.32 | 0.58 | 0.6769 | 0.6788 |
| PERCENTAGE | 3 | 35 | 2.47 | 0.82 | 0.4813 | 0.4902 |
| TREATMENT * PERCENTAGE | 12 | 35 | 18.43 | 1.54 | 0.1033 | 0.1566 |

The test of fixed effects show no significant differences at any of the factors under evaluation in the Isotonic Peak Velocity Right Leg group.

### 4.3.9. Group Isometric Peak torque Right Leg,

Table 23 Test of Fixed Effects Isometric Right leg Peak Torque (Method REML)

| Effect | Num DF | Den DF | Chi-Square | F Value | Pr > ChiSq | Pr > F |
|---|---|---|---|---|---|---|
| TREATMENT | 4 | 35 | 6.45 | 1.61 | 0.1683 | 0.1932 |
| DEGREE | 3 | 35 | 17.27 | 5.76 | 0.0006 | 0.0026 |
| TREATMENT * DEGREE | 12 | 35 | 10.64 | 0.89 | 0.5601 | 0.5680 |

The test of fixed effects show significant differences (Pvalue< 0.05) at the factor degree in the Isotonic Peak Velocity Right Leg group.

### 4.3.10. Group Isometric Peak torque Left Leg,

Table 24 Test of Fixed Effects Isometric Left leg Peak Torque (Method REML)

| Effect | Num DF | Den DF | Chi-Square | F Value | Pr > ChiSq | Pr > F |
|---|---|---|---|---|---|---|
| TREATMENT | 4 | 36 | 9.59 | 2.40 | 0.0480 | 0.0689 |
| DEGREE | 3 | 36 | 5.61 | 1.87 | 0.1319 | 0.1524 |
| TREATMENT * DEGREE | 12 | 36 | 17.05 | 1.42 | 0.1477 | 0.2029 |

The test of fixed effects show significant differences (Pvalue< 0.1) at the factor Degree in the Isotonic Peak Velocity Left Leg group.

## 4.4. INFERENCES

Significant differences at (Pvalue< 0.1) were shown in the group Isometric Peak Torque Left Leg. The inferences based in least square means for this significance and contrast were obtained. (Table 24)

Table 25 Significant Contrast in Group Isometric Peak torque left leg

| Contrasts | | | | |
|---|---|---|---|---|
| Label | Num DF | Den DF | F Value | Pr > F |
| CONTROL VS MET AT VARIABLE ISOM45IH | 1 | 36 | 3.67 | 0.0632 |
| CONTROL VS WBV AT VARIABLE ISOM45IH | 1 | 36 | 2.93 | 0.0956 |
| CONTROL VS WBV AT VARIABLE ISOM90IH | 1 | 36 | 5.13 | 0.0296 |

There are significant differences at (P> 0.1) (Table 24 ) for the contrast control versus microcurrent electrical stimulation in the variable isometric 45 degrees in Hamstring and significant differences (P>0.05) for the contrast control versus whole body vibration in the variable Isometric 90 degrees in the Hamstring. The estimates for this contrast are 6.4125 with standard error 3.3451 and 19.42 with standard error 8.57 respectively, and this estimates show that the control behaves better than the treatments. Although the contrast control versus whole body vibration is not significant at p> 0.1 the information is given to the researchers. The estimates for each contrast are shown in table 25

Table 26 Significant estimates in Group Isometric Peak torque left leg

| Estimates | | | | | |
|---|---|---|---|---|---|
| Label | Estimate | Standard Error | DF | t Value | Pr > \|t\| |
| CONTROL VS MET AT VARIABLE ISOM45IH | 6.4125 | 3.3451 | 36 | 1.92 | 0.0632 |
| CONTROL VS WBV AT ISOM45IH | 5.9250 | 3.4625 | 36 | 1.71 | 0.0956 |
| CONTROL VS WBV AT VARIABLE ISOM90IH | 19.4250 | 8.5759 | 36 | 2.27 | 0.0296 |

## 4.5. RESIDUAL DIAGNOSTICS

For this dataset the residual diagnostic consist of scatter plots of the predicted values versus the studentized residual, the Normal Probability Plot of Predicted Values versus the studentized residual, and histogram of the studentized residual (Appendix figures 7.21 to 7.22), and Shapiro Wilk Normality Test for the studentized residuals (Appendix. Table 7.11)

In general for all of the models the graphical setting shows that the assumption of normality and randomness in the residual is not  fulfilled and also show the presence of outliers.
The Test for Normality shows in the variable isokinetic the normality assumption is close to be accepted the normality hypotesis (near to $P<0.05$).

## 5. DISCUSSION AND CONCLUSION

For the analysis of the dataset were created 10 groups of variables with similar characteristics corresponding to variables of coordination and strength. These groups were: Group Stability in Phase, Group Stability in Antiphase, Group Accuracy in Phase, Group Accuracy in Antiphase, Group Isokinetic Peak torque right leg, Group Isokinetic Peak torque left leg, Group Isotonic Peak Velocity Right Leg, Group Isotonic Peak velocity Left Leg, Group Isometric Peak torque Right Leg, Group Isometric Peak torque Left Leg,

For each group was fitted a repeated measures marginal model considering the different variables for each group as a within-subject factor. Using mixed models technique the covariance and correlation within the variables in each group of variables per subject was considered.

Based in the models proposed it was found the group Isometric Peak torque left leg present significant differences between the control and the treatment Microcurrent Electrical Stimulation in the variable ISOM45IH and the Control and the treatment whole body vibration in the variable ISOM90IH with superior responses in the control group for both of the variables considered.

The residual normality was checked using graphical techniques and was not fulfilled in most of the cases meaning the inferences could not be valid , and also the graphical exploration showed outlier observations, and these outliers can be the responsible for the failure in the normality assumption.

Although, the residual diagnostics for the different models showed the conclusions could not be valid, the conclusions of this report added information for the researchers in the field of rehabilitation therapy for multiple sclerosis patient.

Also, the models fitted for each group of variables (not shown in this report) could be used for physical therapy researcher to design future studies in physical rehabilitation of multiple sclerosis patients involving measures in strength and coordination in the lower limbs.

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## 7. APPENDIX

Figure 7.1. Group Stability in Phase

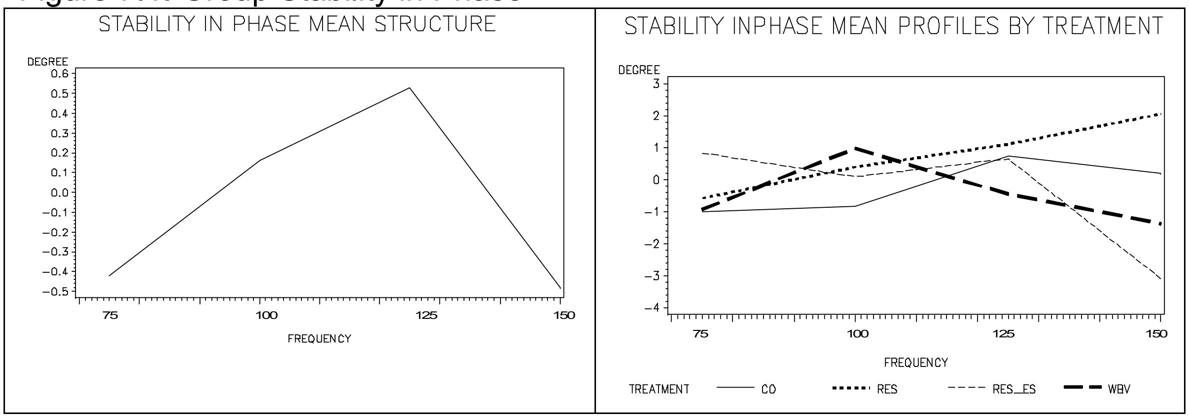


Figure 7.2. Group Stability in Antiphase

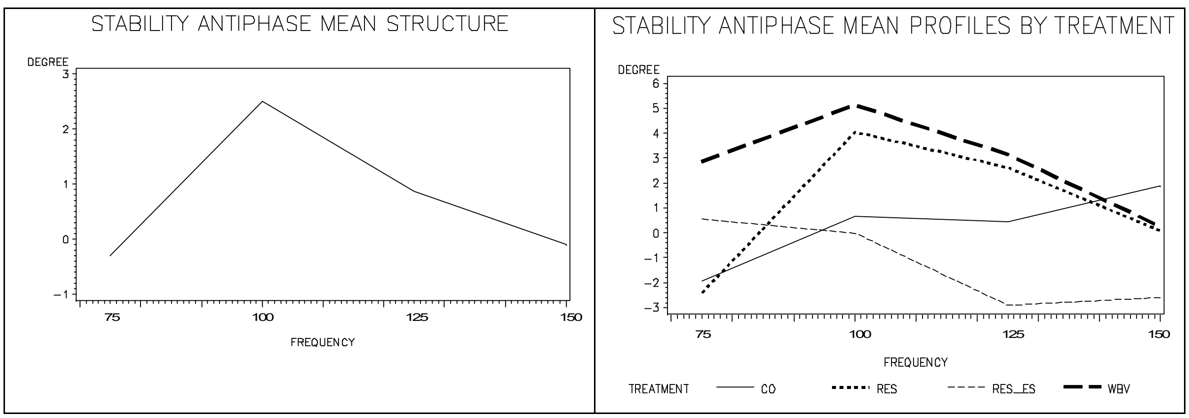


Figure 7.3. Group Accuracy in phase

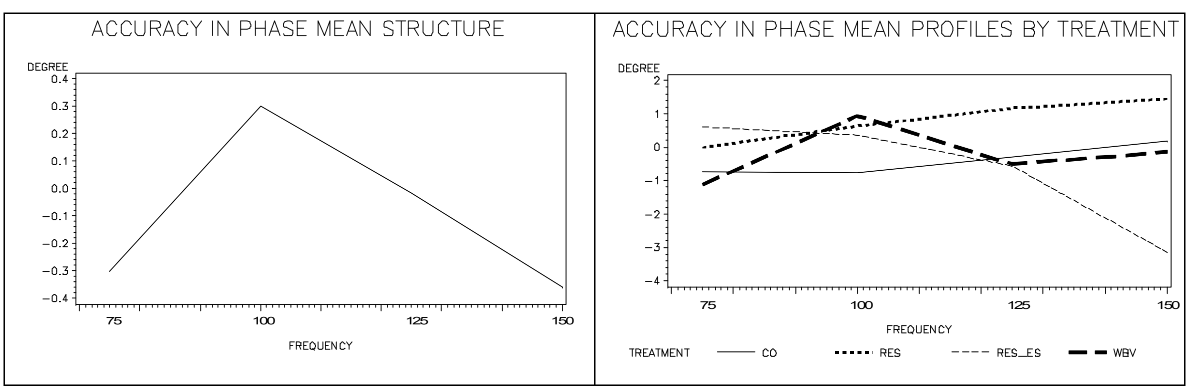

Figure 7.4. Group Accuracy in antiphase

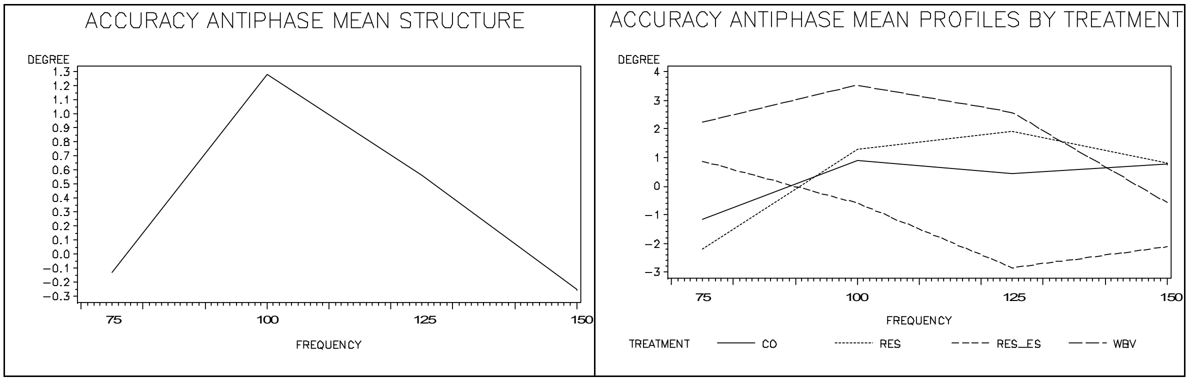


Figure 7.5. Group Isokinetic Peak Torque right leg,

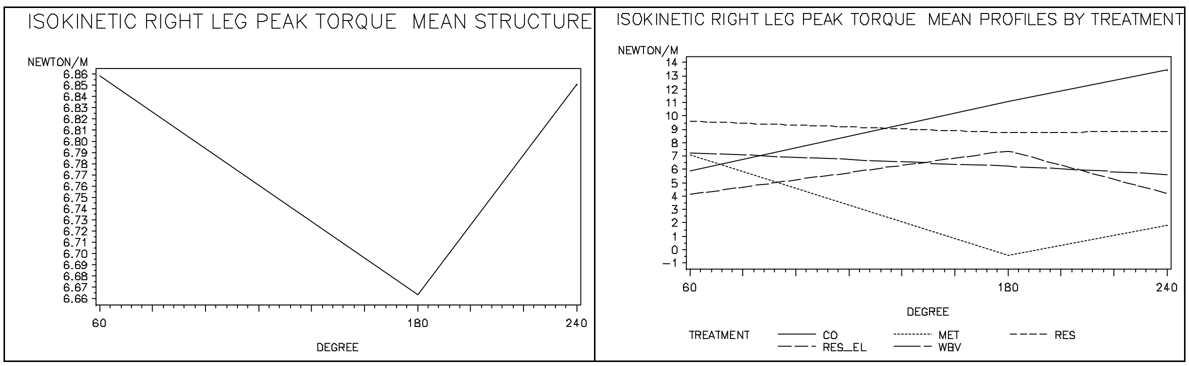


Figure 7.6. Group Isokinetic Peak Torque left leg,

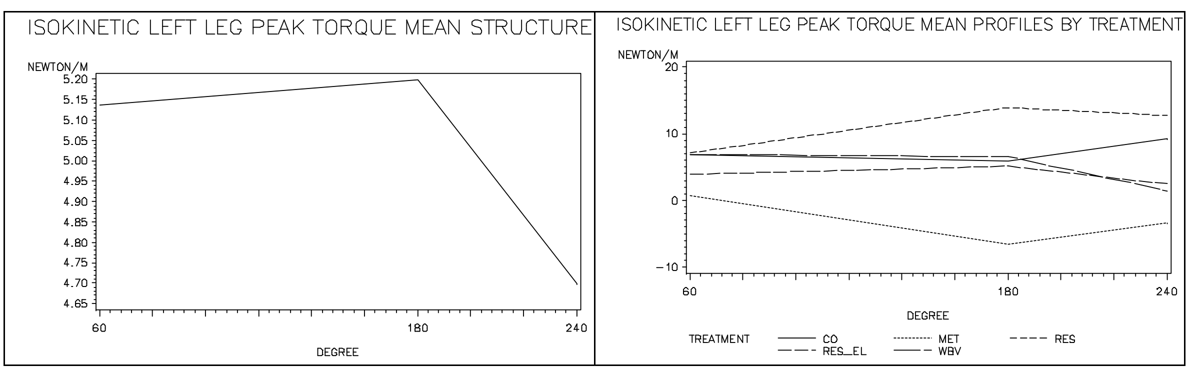

Figure 7.7. Group Isotonic Peak Velocity right leg

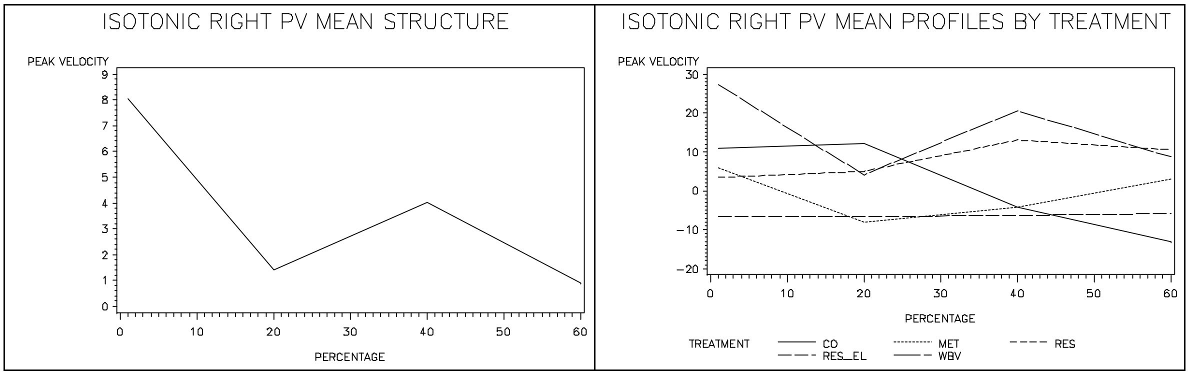


Figure 7.8. Group Isotonic Peak Velocity Left leg

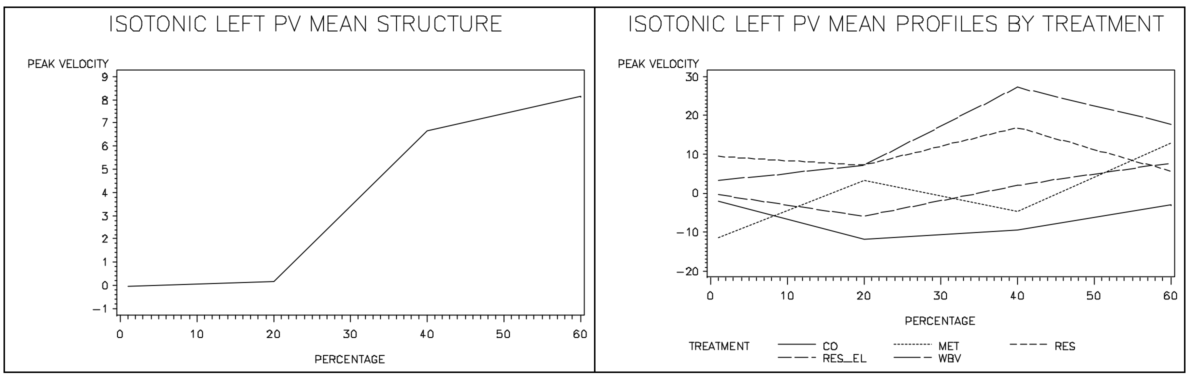


Figure 7.9. Group Isometric Peak torque Right Leg

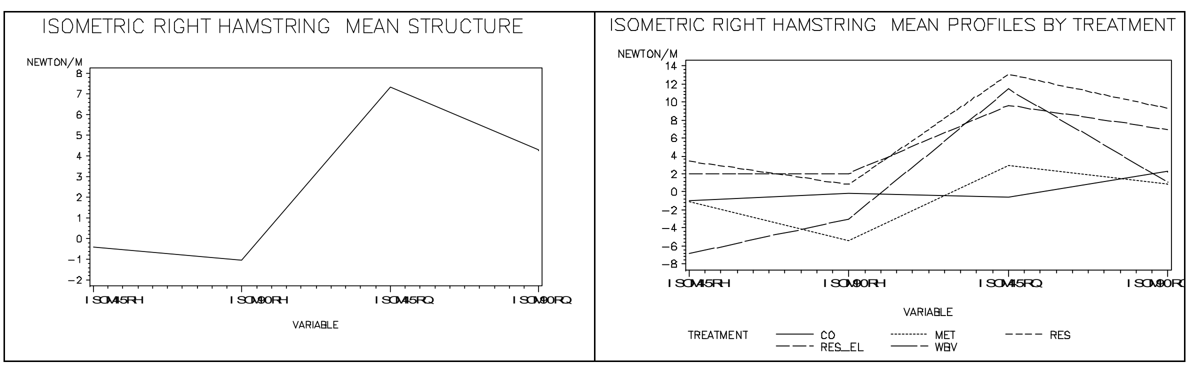

Figure 7.10. Group Isometric Peak torque Left Leg

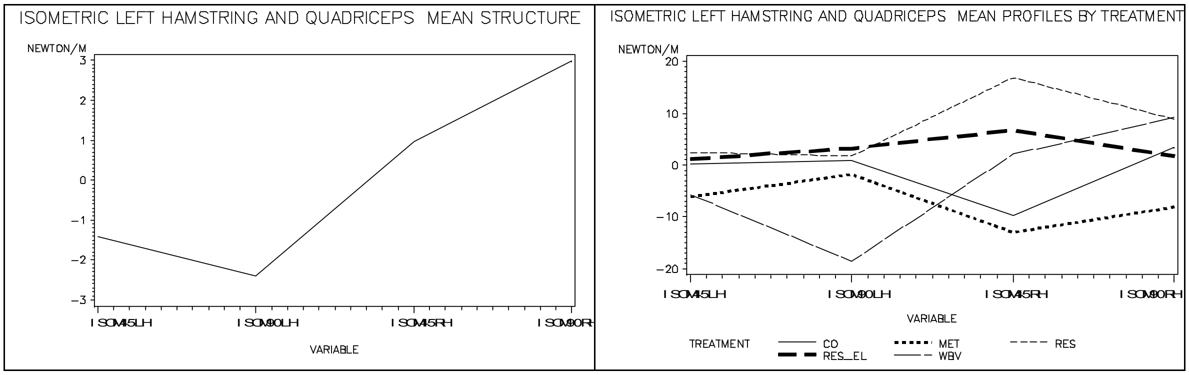


Figure 7.11. Group Stability in Phase

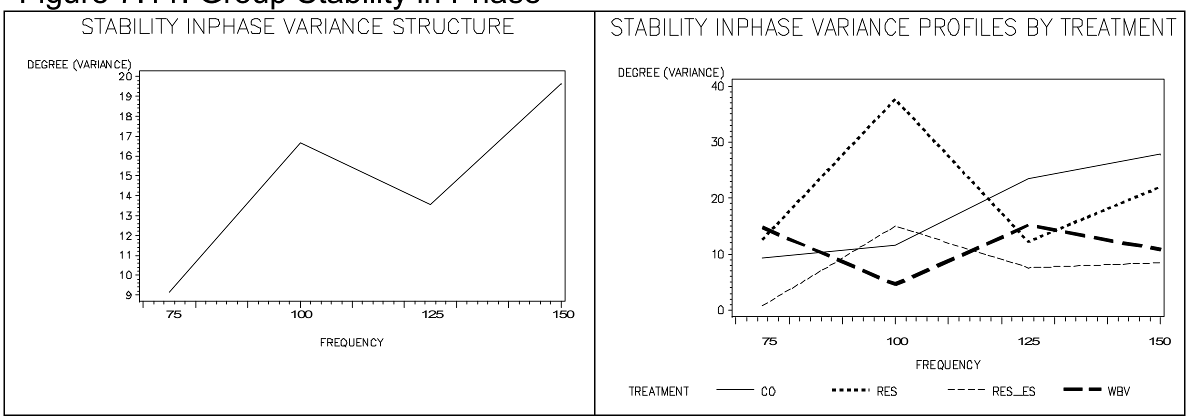


Figure 7.12. Group Stability in Anti Phase

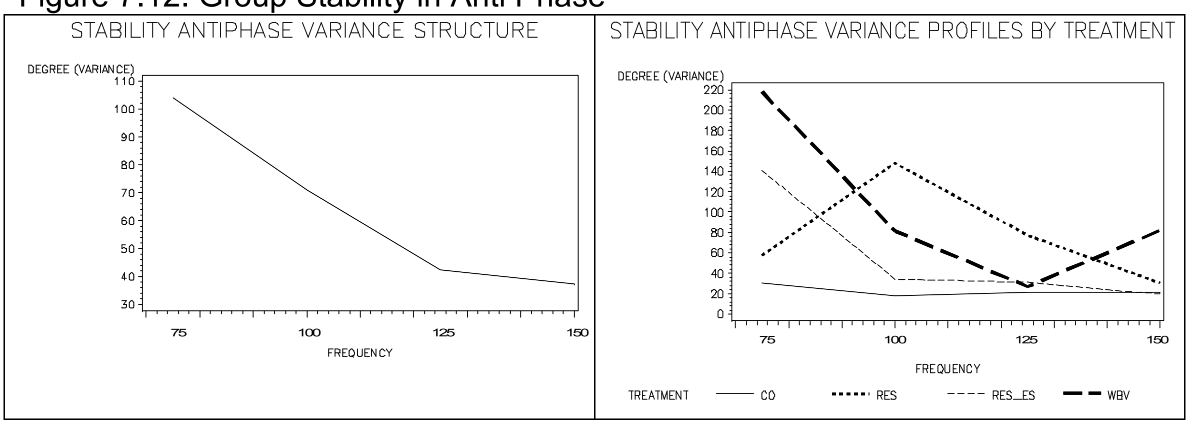

Figure 7.13. Group Accuracy in phase

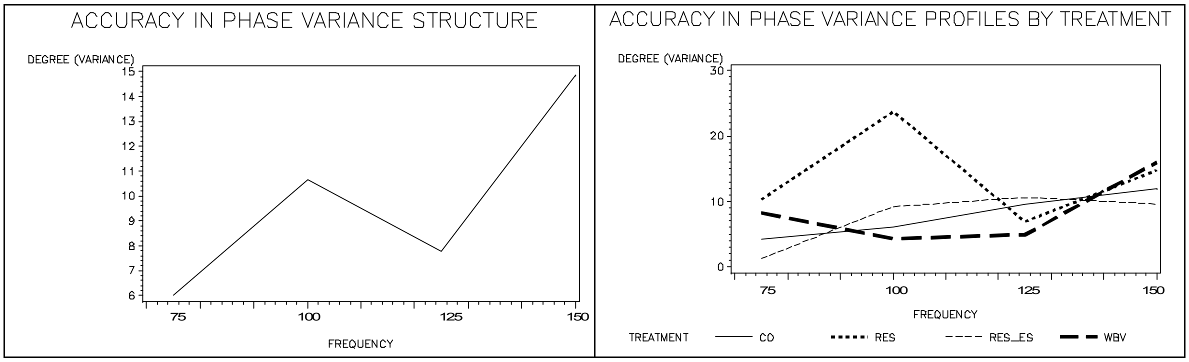


Figure 7.14. Group Accuracy in antiphase

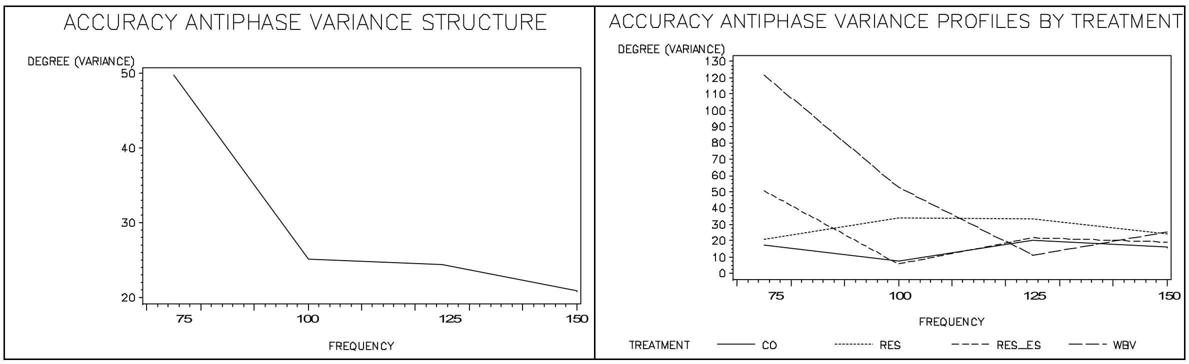


Figure 7.15. Group Isokinetic Peak Torque right leg

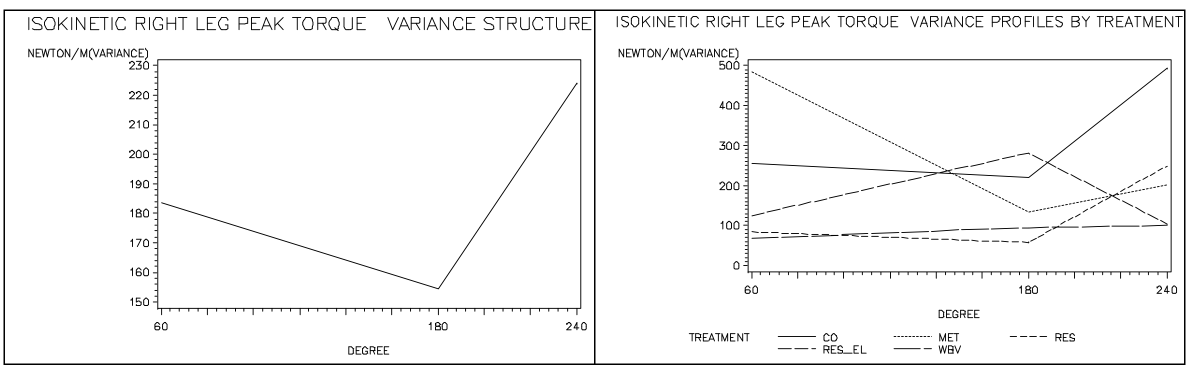

Figure 7.16. Group Isokinetic Peak Torque left leg

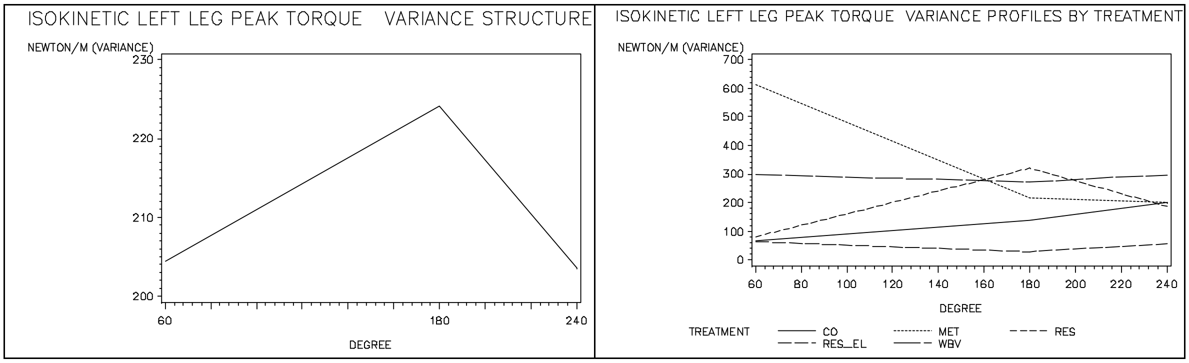


Figure 7.17. Group Isotonic Peak Velocity right leg,

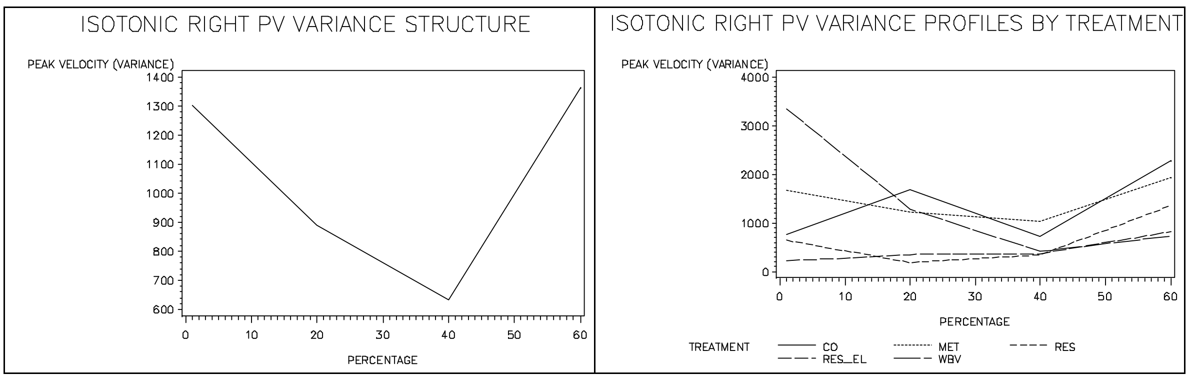


Figure 7.18. Group Isotonic Peak Velocity Left leg,

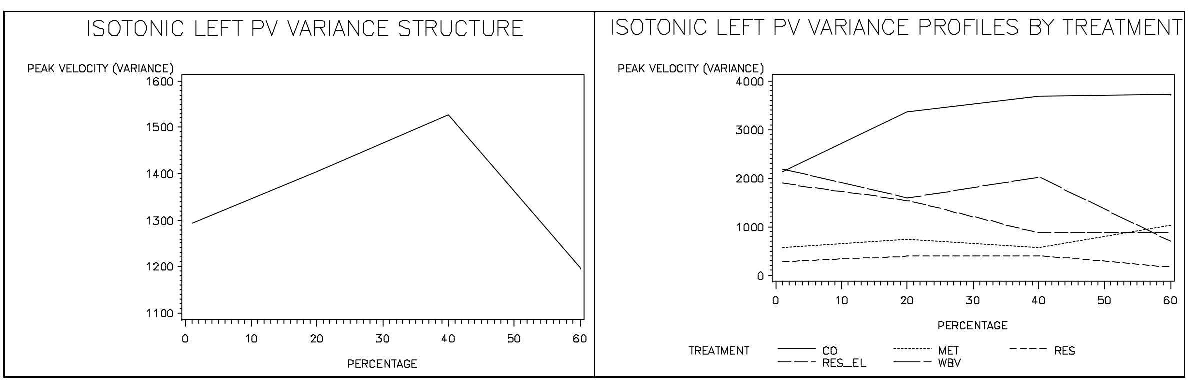

Figure 7.19. Group Isometric Peak Torque Right Leg,

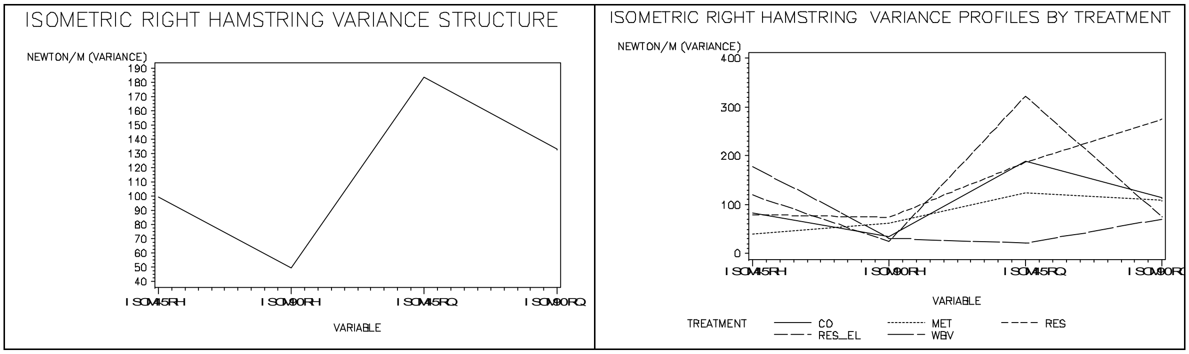


Figure 7.20. Group Isometric Peak Torque Left Leg,

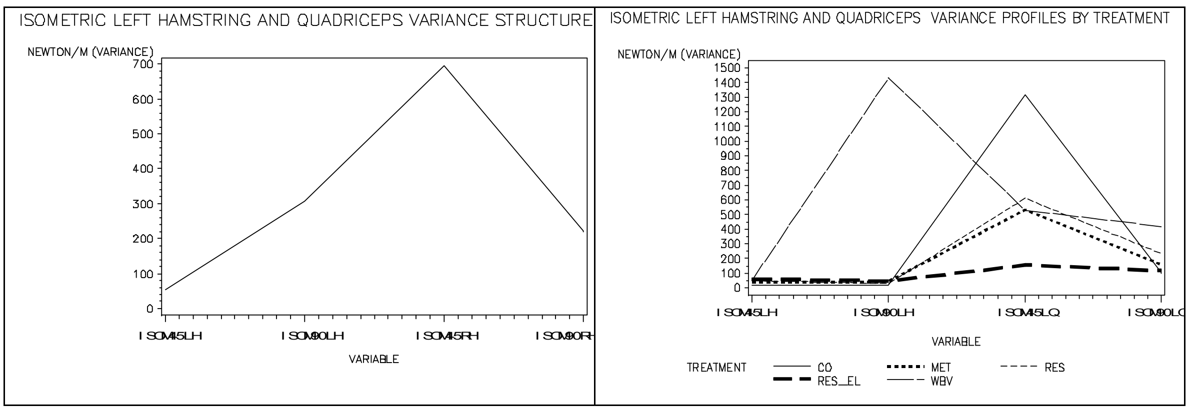


Figure 7.21. Residual Diagnostic Group Stability in Phase

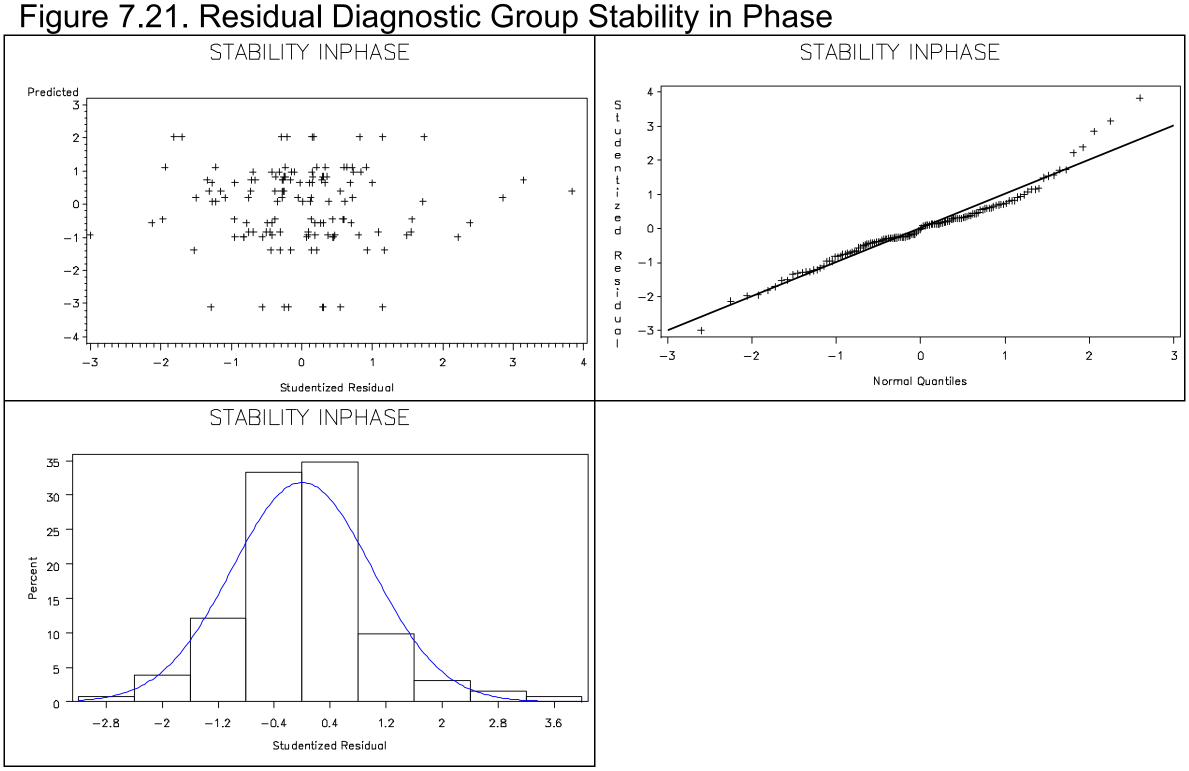

Figure 7.22. Group Stability in antiphase

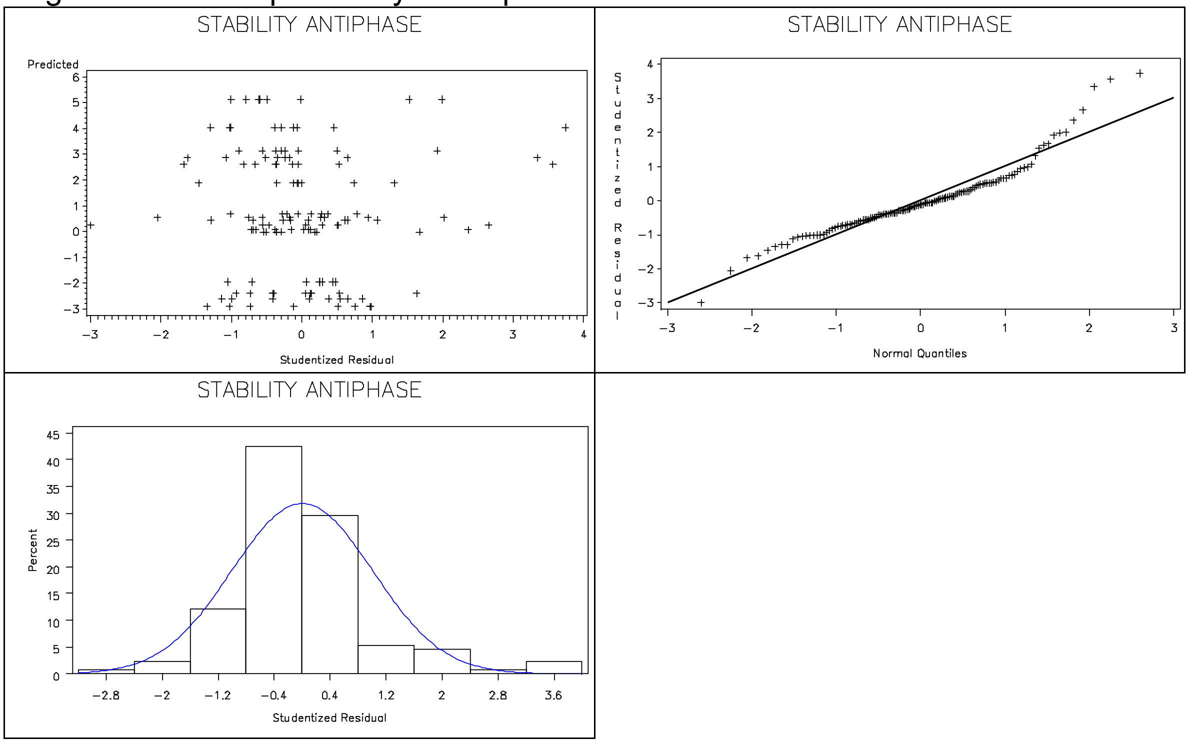


Figure 7.23. Diagnostic Residual Group Accuracy in phase

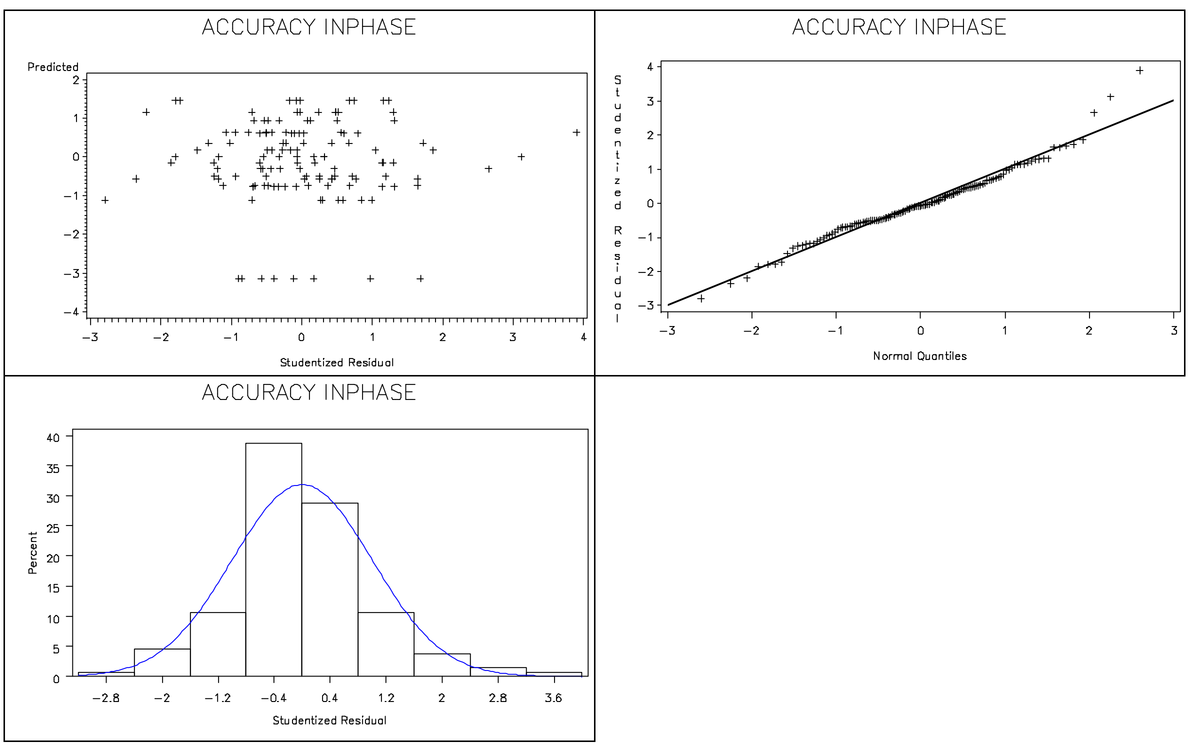

Figure 7.24. Diagnostic Residual Group Accuracy in antiphase

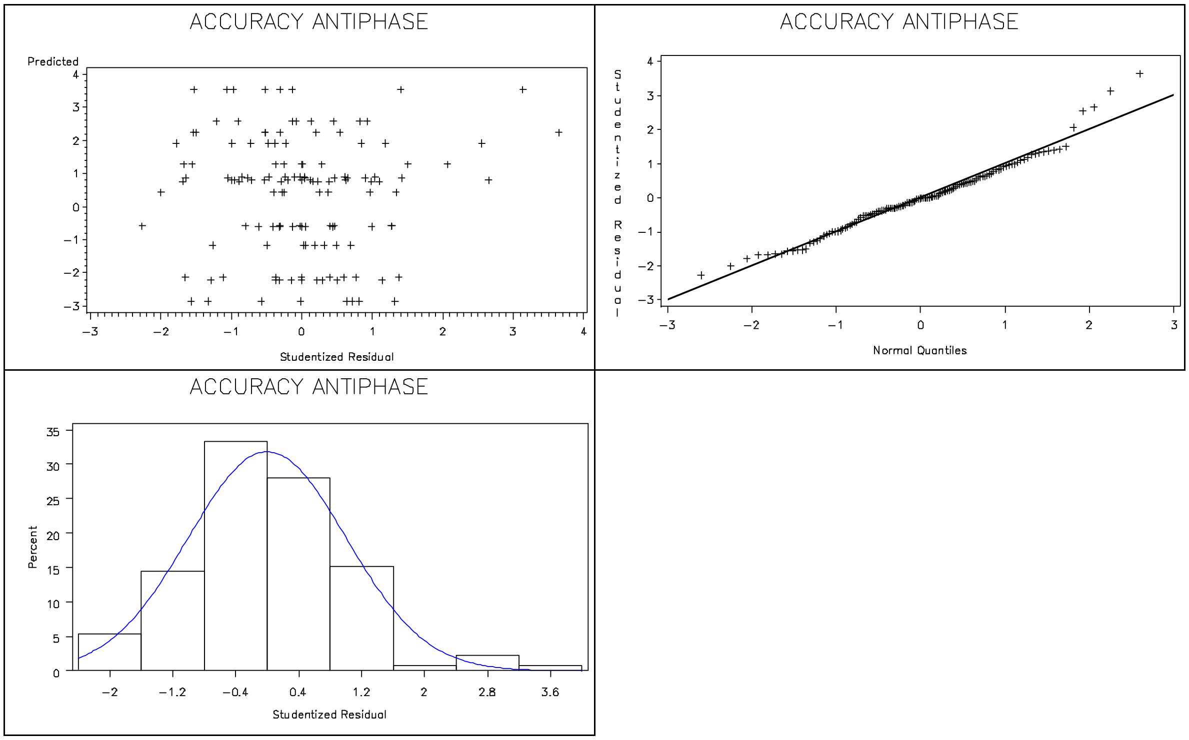


Figure 7.25. Residual Diagnostic Group Isokinetic Peak Torque right leg,

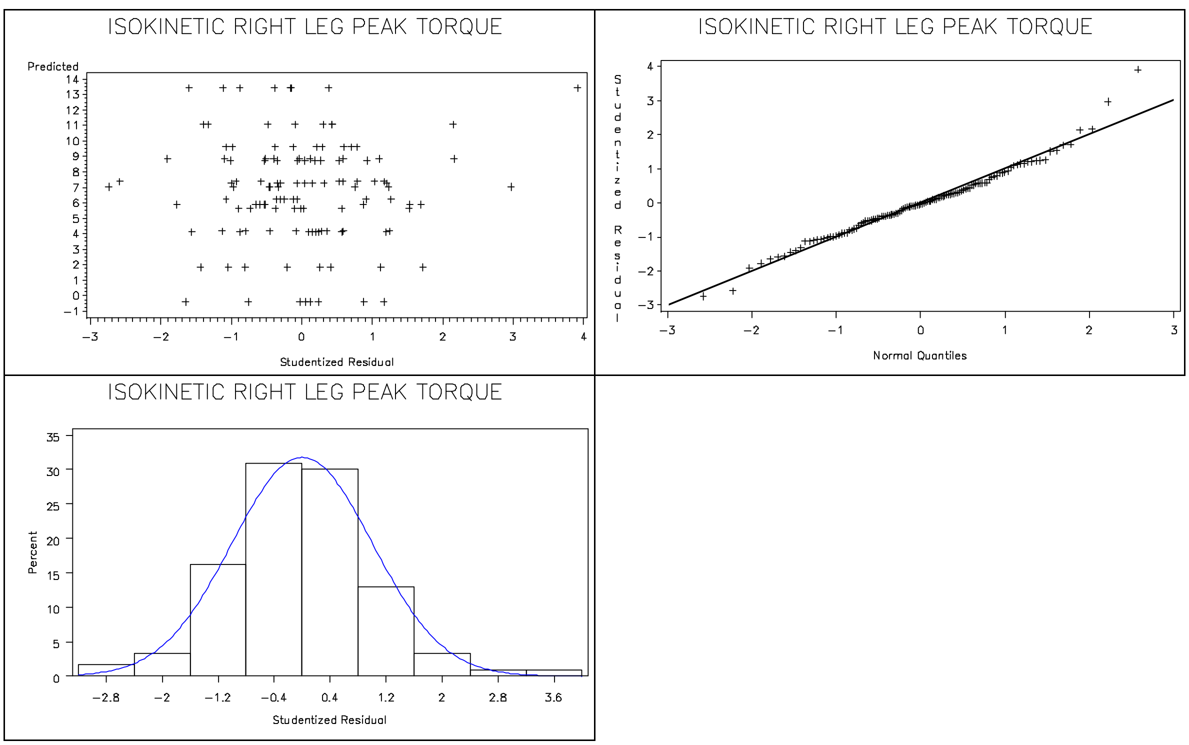

Figure 7.26. Residual Diagnostic Group Isokinetic Peak Torque left leg,

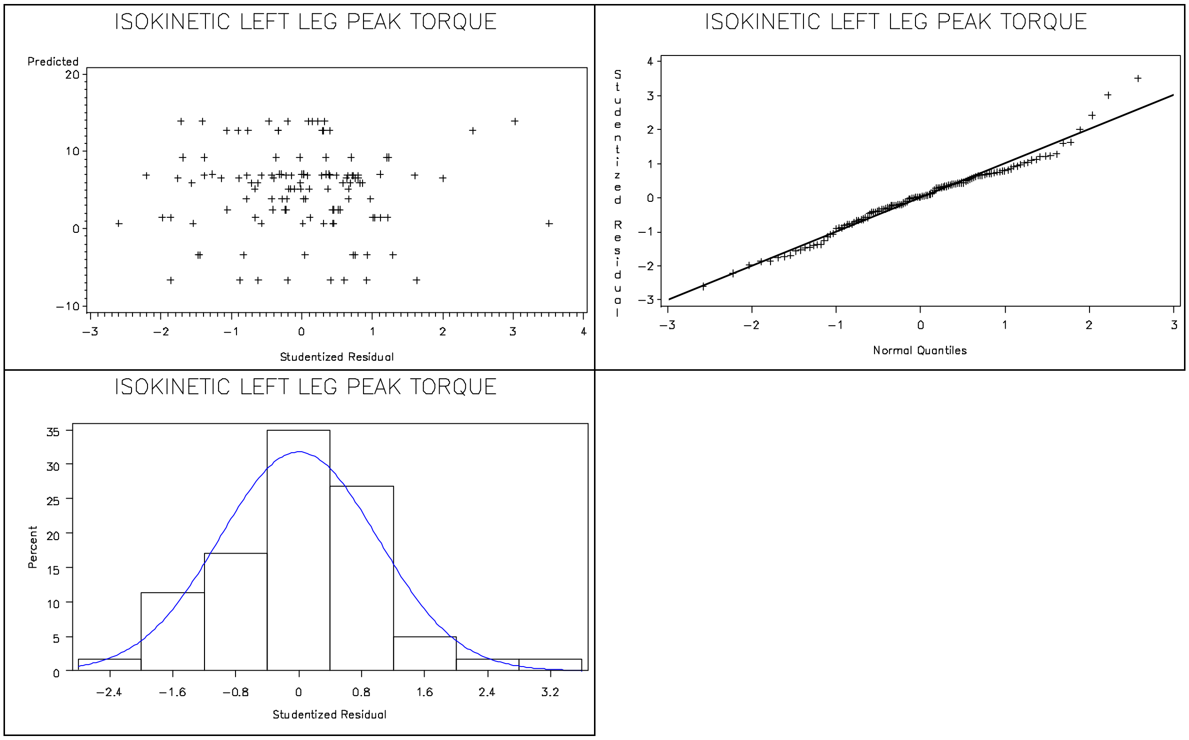


Figure 7.27. Diagnostic Residual Group Isotonic Peak Velocity right leg,

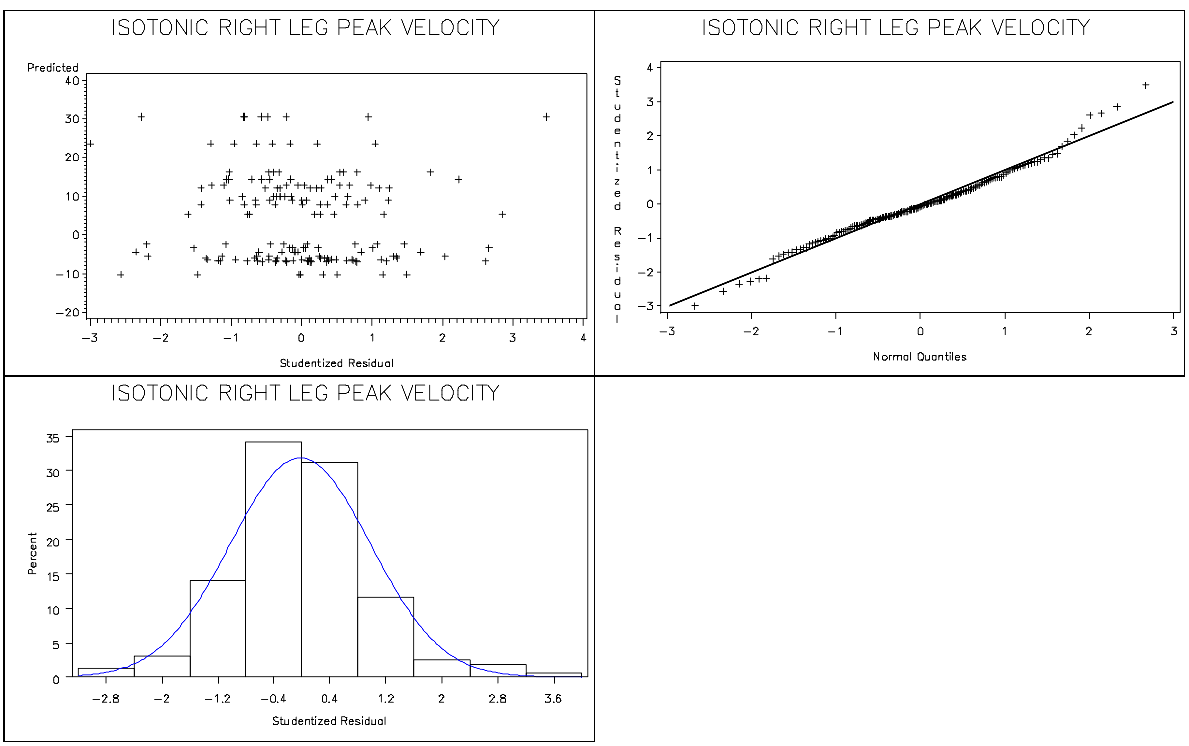

Figure 7.28. Residual Diagnostic Group Isotonic Peak Velocity Left leg,

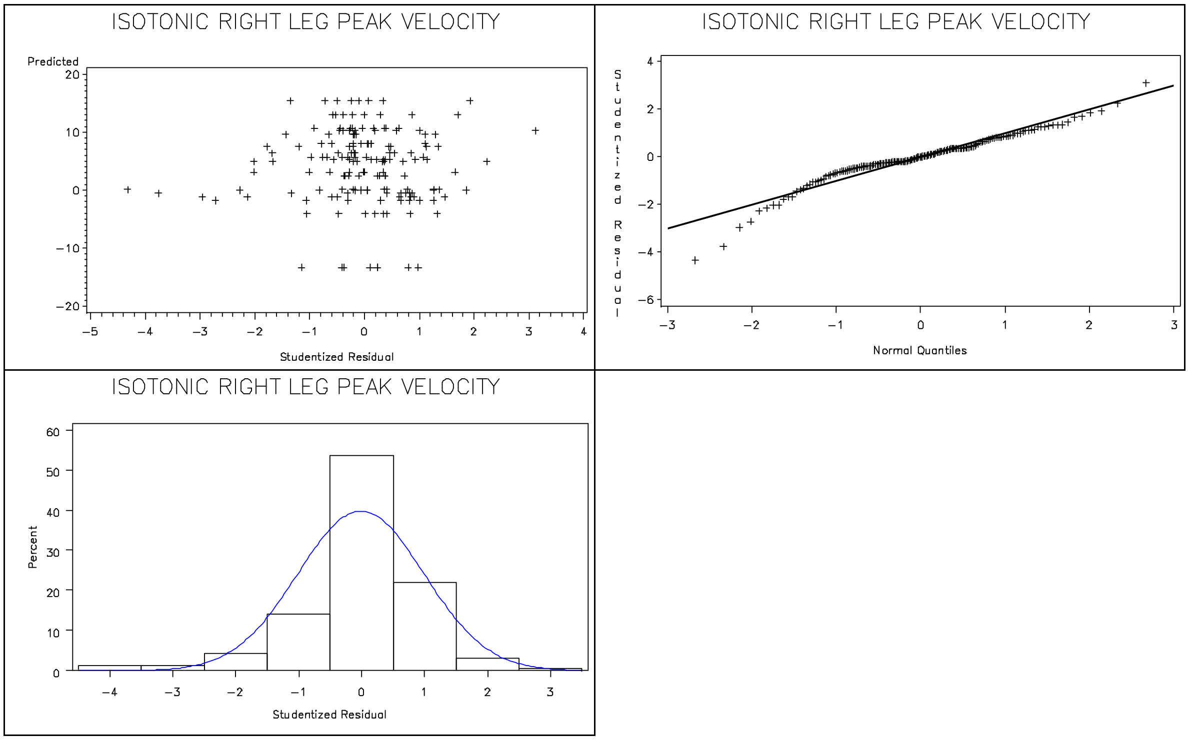


Figure 7.29. Diagnostic Residual Group Isometric Peak torque Right Leg,

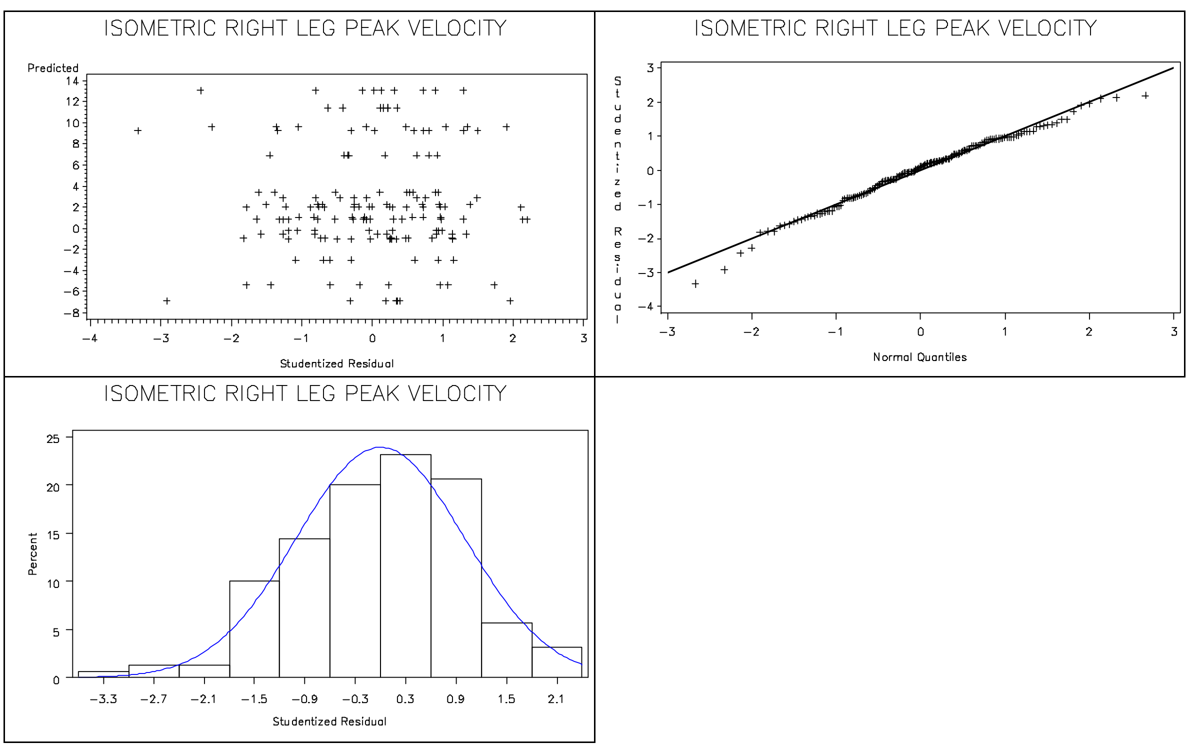

Figure 7.30. Diagnostic Residual  Group Isometric Peak torque Left Leg,

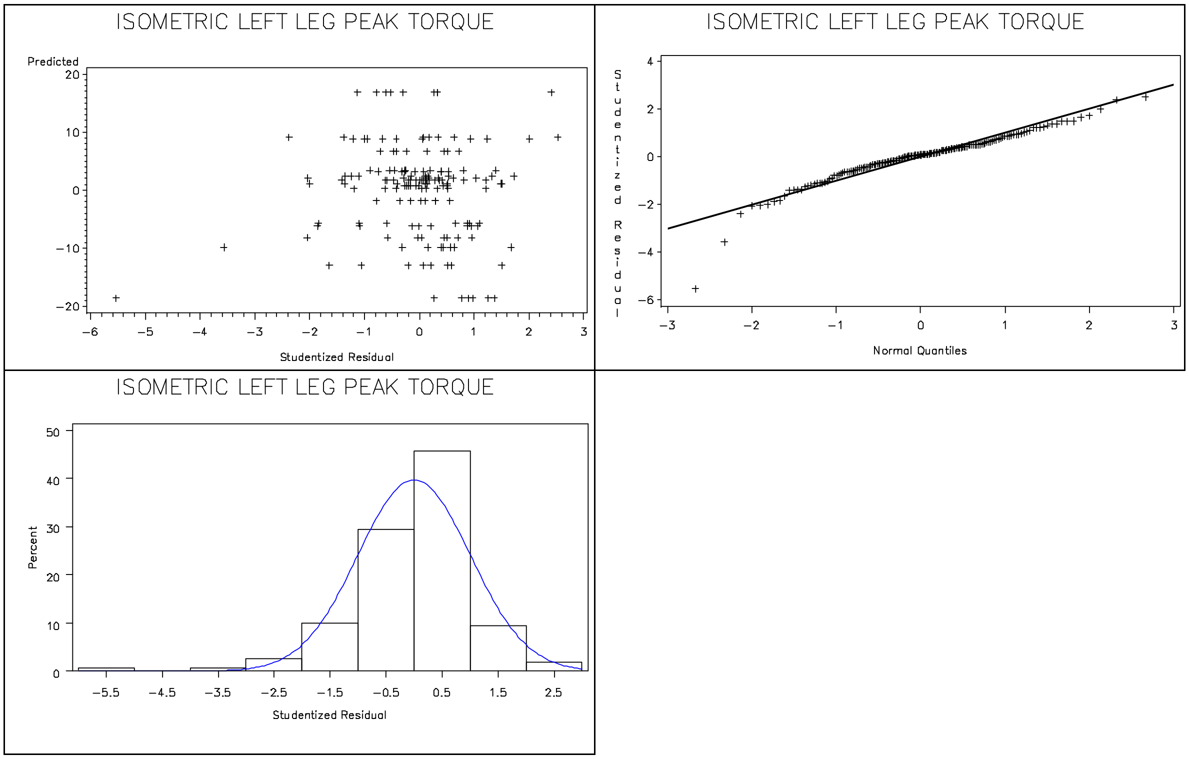


Table 7.1. Correlation structure Group Stability  In Anti Phase

| Pearson Correlation Coefficients, N = 33<br>Prob > \|r\| under H0: Rho=0 | | | | |
|---|---|---|---|---|
| | SD_AF075 | SD_AF100 | SD_AF125 | SD_AF150 |
| SD_AF075 | 1 | 0.60969<br>0.0002 | 0.18538<br>0.3017 | -0.11108<br>0.5383 |
| SD_AF100 | 0.60969<br>0.0002 | 1 | 0.72837<br><.0001 | 0.33924<br>0.0534 |
| SD_AF125 | 0.18538<br>0.3017 | 0.72837<br><.0001 | 1 | 0.75558<br><.0001 |
| SD_AF150 | -0.11108<br>0.5383 | 0.33924<br>0.0534 | 0.75558<br><.0001 | 1 |

Table 7.2. Correlation structure Group Stability  in Phase

| Pearson Correlation Coefficients, N = 33<br>Prob > \|r\| under H0: Rho=0 | | | | |
|---|---|---|---|---|
| | SD_IF075 | SD_IF100 | SD_IF125 | SD_IF150 |
| SD_IF075 | 1 | 0.555<br>0.0008 | 0.56483<br>0.0006 | -0.09912<br>0.5831 |
| SD_IF100 | 0.555<br>0.0008 | 1 | 0.484<br>0.0043 | -0.10059<br>0.5775 |
| SD_IF125 | 0.56483<br>0.0006 | 0.484<br>0.0043 | 1 | 0.37485<br>0.0316 |
| SD_IF150 | -0.09912<br>0.5831 | -0.10059<br>0.5775 | 0.37485<br>0.0316 | 1 |

Table 7.3. Correlation structure Group Accuracy Antiphase

Pearson Correlation Coefficients, N = 33
Prob > |r| under H0: Rho=0

| | AF_AF075 | AF_AF100 | AF_AF125 | AF_AF150 |
|---|---|---|---|---|
| AF_AF075 | 1 | 0.58951 | 0.10893 | -0.14315 |
| | | 0.0003 | 0.5462 | 0.4268 |
| AF_AF100 | 0.58951 | 1 | 0.59947 | 0.22885 |
| | 0.0003 | | 0.0002 | 0.2002 |
| AF_AF125 | 0.10893 | 0.59947 | 1 | 0.74323 |
| | 0.5462 | 0.0002 | | <.0001 |
| AF_AF150 | -0.14315 | 0.22885 | 0.74323 | 1 |
| | 0.4268 | 0.2002 | <.0001 | |

Table 7.4. Correlation structure Group Accuracy In phase

Pearson Correlation Coefficients, N = 33
Prob > |r| under H0: Rho=0

| | AF_IF075 | AF_IF100 | AF_IF125 | AF_IF150 |
|---|---|---|---|---|
| AF_IF075 | 1 | 0.48876 | 0.29423 | -0.19287 |
| | | 0.0039 | 0.0965 | 0.2822 |
| AF_IF100 | 0.48876 | 1 | 0.40311 | -0.06195 |
| | 0.0039 | | 0.02 | 0.732 |
| AF_IF125 | 0.29423 | 0.40311 | 1 | 0.49682 |
| | 0.0965 | 0.02 | | 0.0033 |
| AF_IF150 | -0.19287 | -0.06195 | 0.49682 | 1 |
| | 0.2822 | 0.732 | 0.0033 | |

Table 7.5. Correlation structure Group Isokinetic Peak Torque right leg

Pearson Correlation Coefficients, N = 41
Prob > |r| under H0: Rho=0

| | ISOKr60PT | ISOKr180PT | ISOKr240PT |
|---|---|---|---|
| ISOKr60PT | 1 | 0.6626 | 0.50757 |
| | | <.0001 | 0.0007 |
| ISOKr180PT | 0.6626 | 1 | 0.75999 |
| | <.0001 | | <.0001 |
| ISOKr240PT | 0.50757 | 0.75999 | 1 |
| | 0.0007 | <.0001 | |

Table 7.6. Correlation structure Group Isokinetic Peak Torque left leg,

| Pearson Correlation Coefficients, N = 41<br>Prob > \|r\| under H0: Rho=0 | | | |
|---|---|---|---|
| | ISOKl60PT | ISOKl180PT | ISOKl240PT |
| ISOKl60PT | 1 | 0.57955<br><.0001 | 0.46066<br>0.0024 |
| ISOKl180PT | 0.57955<br><.0001 | 1 | 0.83702<br><.0001 |
| ISOKl240PT | 0.46066<br>0.0024 | 0.83702<br><.0001 | 1 |

Table 7.7. Correlation structure Group Isotonic Peak Velocity right leg,

| Pearson Correlation Coefficients, N = 41<br>Prob > \|r\| under H0: Rho=0 | | | | |
|---|---|---|---|---|
| | ISOTr1_Pv | ISOTr20_Pv | ISOTr40_PV | ISOTr60_Pv |
| ISOTr1_Pv | 1 | 0.69263<br><.0001 | 0.33515<br>0.0322 | 0.19045<br>0.233 |
| ISOTr20_Pv | 0.69263<br><.0001 | 1 | 0.42031<br>0.0062 | 0.31773<br>0.0429 |
| ISOTr40_PV | 0.33515<br>0.0322 | 0.42031<br>0.0062 | 1 | 0.75588<br><.0001 |
| ISOTr60_Pv | 0.19045<br>0.233 | 0.31773<br>0.0429 | 0.75588<br><.0001 | 1 |

Table 7.8. Correlation structure Group Isotonic Peak Velocity Left leg,

| Pearson Correlation Coefficients, N = 41<br>Prob > \|r\| under H0: Rho=0 | | | | |
|---|---|---|---|---|
| | ISOTl1_Pv | ISOTl20_Pv | ISOTl40_PV | ISOTl60_Pv |
| ISOTl1_Pv | 1 | 0.69324<br><.0001 | 0.41298<br>0.0073 | 0.13313<br>0.4066 |
| ISOTl20_Pv | 0.69324<br><.0001 | 1 | 0.75053<br><.0001 | 0.50899<br>0.0007 |
| ISOTl40_PV | 0.41298<br>0.0073 | 0.75053<br><.0001 | 1 | 0.76969<br><.0001 |
| ISOTl60_Pv | 0.13313<br>0.4066 | 0.50899<br>0.0007 | 0.76969<br><.0001 | 1 |

Table 7.9. Correlation structure Group Isometric Peak torque Right Leg,

| Pearson Correlation Coefficients, N = 40<br>Prob > \|r\| under H0: Rho=0 | | | | |
|---|---|---|---|---|
| | ISOM45rH | ISOM90rH | ISOM45rQ | ISOM90rQ |
| ISOM45rH | 1 | 0.54654<br>0.0003 | 0.11241<br>0.4898 | 0.40438<br>0.0097 |
| ISOM90rH | 0.54654<br>0.0003 | 1 | 0.25288<br>0.1154 | 0.42752<br>0.0059 |
| ISOM45rQ | 0.11241<br>0.4898 | 0.25288<br>0.1154 | 1 | 0.52292<br>0.0005 |
| ISOM90rQ | 0.40438<br>0.0097 | 0.42752<br>0.0059 | 0.52292<br>0.0005 | 1 |

Table 7.10. Correlation structure Group Isometric Peak torque Left Leg

| Pearson Correlation Coefficients, N = 40<br>Prob > \|r\| under H0: Rho=0 | | | | |
|---|---|---|---|---|
| | ISOM45lH | ISOM90lH | ISOM45lQ | ISOM90lQ |
| ISOM45Lh | 1 | 0.54789<br>0.0003 | 0.47805<br>0.0018 | 0.39048<br>0.0127 |
| ISOM90lH | 0.54789<br>0.0003 | 1 | 0.35583<br>0.0242 | -0.27253<br>0.0889 |
| ISOM45lQ | 0.47805<br>0.0018 | 0.35583<br>0.0242 | 1 | 0.28703<br>0.0725 |
| ISOM90lQ | 0.39048<br>0.0127 | -0.27253<br>0.0889 | 0.28703<br>0.0725 | 1 |

Table 7.11. Shapiro Wilk Normality Test For Studentized Residuals

| | W | Pr< W |
|---|---|---|
| Stability in Phase | 0.960644 | 0.0007 |
| Stability antiphase | 0.919669 | <0.0001 |
| Accuracy inphase | 0.971349 | 0.0068 |
| Accuracy antiphase | 0.97173 | 0.0074 |
| Isokinetic right Peak Torque | 976536 | 0.0305 |
| Isokinetic left Peak Torque | 0.976988 | 0.0336 |
| Isotonic right Peak Velocity | 0.979797 | 0.0169 |
| Isotonic Left Peak Velocity | 0.939933 | <0.0001 |
| Isometric rigth Peak Torque | 0.985924 | 0.106 |
| Isometric left Peak Torque | 0.922723 | <0.0001 |

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