

MyotonPRO is a reliable and repeatable tool for measuring mechanical properties of the upper limb muscles in patients with chronic stroke

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Abstract

The purpose of the present study was to investigate the inter-rater and intra-rater reliability of the MyotonPRO for measuring the mechanical properties of the upper limb muscles in patients with chronic stroke. The study was conducted with 20 stroke patients (14 males, 6 females) with age range of 36–84 years (65.1 ± 11.2 years). The oscillation frequency, stiffness, and logarithmic decrement of the biceps brachii, triceps brachii, deltoid, and upper trapezius muscles were measured using a MyotonPRO (Muomeetria Ltd., Tallinn, Estonia). The measurements were conducted by two physiotherapists to determine the inter-rater reliability of the device. A physiotherapist repeated the measurements 3 days after the first measurements for determining the intra-rater reliability of the device. The ICCs of the all assessed muscles ranged between 0.72 and 0.97. The coefficient of variation of all muscles ranged within 3.2%-11.0%, from 3.4–9.7% for oscillation frequency, from 3.9–7.4% for stiffness, and from 3.2–11.0% for decrement. The standard error of measurement in the assessed muscles ranged from 0.5 to 1.2 Hz for frequency, from 9.2 to 21.2 N/m for stiffness, and from 0.1 to 0.4 for decrement. The results obtained show that MyotonPRO has a good to excellent intra-rater and inter-rater reliability for measuring the tone, stiffness, and elasticity of the deltoid, biceps brachii, triceps brachii, and upper trapezius muscles in patients with chronic stroke. MyotonPRO can be used for the diagnostic and therapeutic intention in patients with chronic stroke.

Introduction

Stroke is a general health problem worldwide, and it is one of the major causes of disability in adults^{1,2}. One of the most common deficits after stroke is upper limb impairment, which can cause functional limitations in daily life activities^{3,4}. Upper limb impairment in stroke patients is associated with impaired detection of sensory information and disturbed performance of motor tasks⁵. One of the most prevalent causes of the disturbed performance of motor tasks following stroke is changes in muscle mechanical properties, such as tone, stiffness, or elasticity^{6,7}. Many medical treatments and rehabilitative approaches are used to regulate the muscle tone, stiffness, or elasticity in stroke patients with upper limb impairment. A reliable and valid method for measuring muscle tone, stiffness and elasticity could show the effectiveness of these treatment modalities, the progression, and the success of interventions.

There are some options used to measure muscle mechanical properties. These methods have some advantages and disadvantages. The Modified Ashworth Scale is (MAS) the most widely used method to evaluate muscle tone. The MAS allows a practical and rapid assessment for measuring muscle tone; however, it is not sufficiently sensitive to detect small changes in muscle tone, does not allow the measurement of activated muscle tone, and does not assess the tone of an isolated muscle^{8,9}. Furthermore, the magnetic resonance and ultrasonography provide reliable and valid assessment of the soft tissue stiffness; however, these devices are expensive, take too much time, and do not allow the assessments to be performed in different environments. Because of these reasons, magnetic resonance imaging and ultrasonography are not too suitable to use in clinical practises. On the other hand, the

myotonometer is a portable device which allows assessments to be performed in different environments. In addition, it is a simple device, and one can learn how to use it easily.

There are various studies in the literature that investigated the reliability of the myotonometer. An important point of these studies was that they were conducted in healthy participants. There are a few studies which investigated the reliability of the myotonometer for measuring muscle mechanical properties in stroke patients. However, some of them were conducted in patients with acute stroke¹⁰⁻¹², and some of them used the Myoton-3 myometer (a previous version of MyotonPRO)^{10,13,14}. On the other hand, inter-rater reliability of the MyotonPRO was only investigated in patients with acute stroke by one study¹¹. To our knowledge, there is no study which investigated the reliability of the MyotonPRO in patients with chronic stroke. Therefore, the purpose of the present study was to investigate the inter-rater and intra-rater reliability of the MyotonPRO for measuring the mechanical properties of the upper limb muscles in patients with chronic stroke. It was hypothesized that MyotonPRO would have sufficient inter-rater and intra-rater reliability to measure the mechanical properties of the upper limb muscles in patients with chronic stroke.

Material And Methods

Sample-Size Calculation

Simple size calculation was performed to determine the minimum sample size. Sample size calculation was performed based on an expected intraclass correlation coefficient of 0.85, a desired power level of 80%, and an alpha level of 0.5. The sample size calculation showed that the study must be conducted with at least 15 participants^{15,16}.

Participants

The study was conducted in 20 stroke patients (14 males, 6 females) in an age range of 36–84 years (65.1 ± 11.2 years). Chronic stroke patients with a stroke onset of at least 6 months were included in the study. Patients were excluded if they reported: (1) having a severe cognitive impairment, (2) having an onset of first ever stroke less than 6 months or more than 18 months, (3) having other neurologic, neuromuscular, or orthopaedic disease, (4) having excessive spasticity in the upper limbs that might prevent the patient from taking the measurement position, (5) using an anti-spastic drug (e.g., botulinum toxin type A) during the study period, (6) having body mass index more than 30 kg/m, and (7) performing any strenuous exercises within the 24 h prior to measurements.

The present study was approved by the Non-Invasive Clinical Research Ethics Board of Mersin University (Protocol Number: 2020/517).

Oral and written informed consents were obtained from each participant prior to experiment.

The present study was conducted in accordance with the relevant guidelines and regulations of the local institute.

Procedure

The oscillation frequency, stiffness, and logarithmic decrement of the biceps brachii, triceps brachii, deltoid, and upper trapezius muscles were selected to determine the inter-rater and intra-rater reliability of the MyotonPRO. The measurements were conducted by two physiotherapists. Before the study, both evaluators practiced MyotonPRO on the muscles being evaluated to minimize the learning effect caused by unfamiliarity with the device. Each participant was evaluated at 30-minute intervals by two evaluators. Both raters were unaware of the results during the measurements. A physiotherapist repeated the measurements 3 days after the first measurements to assess the intra-rater reliability of the device. The measurements of the oscillation frequency, stiffness, and logarithmic decrement were performed at the same time of the day (± 1 h). For each muscle measured, 3 consecutive measurements were conducted at 30-second intervals and the average value of these 3 measurements was used for analysis.

Equipment

The oscillation frequency, stiffness, and logarithmic decrement of the biceps brachii, triceps brachii, deltoid, and upper trapezius muscles were measured using a MyotonPRO (Muomeetria Ltd., Tallinn, Estonia). The MyotonPRO measures mechanical oscillations in the evaluated tissue by applying a mechanical impulse with a short duration (15 milliseconds) and a constant mechanical force (up to 0.6 N). After applying mechanical impulse, measuring the mechanical oscillations provides the following data: (1) oscillation frequency (Hz), (2) stiffness (N/m), and (3) logarithmic decrement. Oscillation frequency (Hz) shows the tone of a muscle in its resting or passive state without any contraction. Dynamic stiffness (N/m) provides information about its resistance to an external force or a contraction. Logarithmic decrement provides information about the elasticity of the assessed soft tissue. Elasticity shows the ability to return its previous shape after a removal of an external force or a contraction of deformation ¹⁷.

The measurements of oscillation frequency, stiffness, and logarithmic decrement of the assessed muscles were performed on the affected side of the upper limb. Measurements were performed while the patient is sitting in a chair with a back support. Measurements were made while arm weight was in a position supported by a pillow, elbow at 45° flexion, shoulder at 45° elevation, and the forearm was between pronation and supination. For the upper trapezius measurements, the probe of the device was positioned at 2 cm lateral of the midway between the lateral edge of the spinous process of C7 and acromion. The biceps brachii measurements were performed at the long head of the muscle in the middle of the arm. The triceps brachii measurements were performed at the medial head of the muscle in the middle of the arm. Deltoid measurements were performed at the middle part of the muscle in the plumpest portion of the muscle.

Statistical Analysis

Statistical analyses were conducted using a software program (SPSS version 22, IBM Corporation, Armonk, New York, USA). Descriptive data are presented as mean and standard deviation for the

assessed parameters. Intraclass correlation coefficient (ICC) was used to determine the reliability of the device. The intra-rater reliability of the device was tested using ICC_{3,1} (2-way mixed model consistency). The ICC_{2,2} (2-way random-effect model, absolute agreement) was used to determine the inter-rater reliability. For every comparison, the standard error of measurement (SEM), the coefficient of variation (CV), and the minimum detectable change

(MDC) were calculated according to following formulas: $[SEM = SD \times \sqrt{(1 - ICC)}]$,

$[CV = \left(\frac{SEM}{Mean}\right) \times 100 \text{ \%}]$, $[MDC = \sqrt{2} \times 1.96 \times SEM]$, respectively. Bland and Altman analysis

was used to identify the systematic bias. Correlation analysis results were interpreted as follows:

0.81–1.00 (excellent), 0.61–0.80 (good), 0.41–0.60 (moderate), 0.21–0.40 (fair), and 0.00–0.20

(poor).

Results

The mean time since cerebrovascular disease onset \pm standard deviation was 9.70 \pm 3.31 months. Nineteen patients with stroke had a right hemiplegia. All patients had upper limb spasticity. Table 1 shows the demographic and clinical characteristics of the patients.

The results of the inter-rater reliability assessment are presented in Table 2. Excellent reliability was found for the assessed muscles, with a range of 0.81 to 0.92, with the exception of frequency in the biceps brachii (ICC: 0.78) and triceps brachii (ICC: 0.76), and the decrement in the triceps brachii (ICC: 0.75) and upper trapezius (ICC: 0.74). CV values of the tested muscles ranged from 3.9% to 9.7%. The SEMs of the assessed muscles ranged from 0.6 to 1.2 Hz for frequency, 9.2 to 21.0 N/m for stiffness, and 0.1 to 0.4 for decrement. The MDCs of all the muscles ranged from 1.7 to 3.4 Hz for frequency, 25.6 to 58.3 N/m for stiffness, and 0.2 to 0.6 for decrement.

The results of the intra-rater reliability assessment are given in Table 3. Excellent reliability was found for the assessed muscles, in a range of 0.81 to 0.97, with the exception of stiffness in the deltoid (ICC: 0.74), and decrement in the biceps brachii (ICC: 0.72) and deltoid (ICC: 0.78). CV values of the tested muscles ranged from 3.2% to 11%. The SEMs of the assessed muscles ranged from 0.5 to 0.7 Hz for frequency, 9.4 to 21.2 N/m for stiffness, and 0.1 to 0.2 for decrement. The MDCs of all the muscles ranged from 1.3 to 2.3 Hz for frequency, 25.4 to 59.1 N/m for stiffness, and 0.1 to 0.5 for decrement.

Bland and Altman plots for the frequency of the pooled data of the assessed muscles are presented in Figures 1 and 2. Bland and Altman plots for all the assessed muscles in frequency, stiffness, and decrement parameters show that there was no systematic bias between the two raters as well as between the two testing time points.

Discussion

To our knowledge, this is the first study investigating the intra-rater and inter-rater reliability of the MyotonPRO device in measuring the mechanical properties of the upper limb muscles in patients with chronic stroke. The hypothesis of this study was that the MyotonPRO would have enough inter-rater and intra-rater reliability to measure the mechanical properties of the upper limb muscles in stroke patients. In line with the hypothesis, it was found that the MyotonPRO had a good to excellent inter-rater and intra-rater reliability (ICC: 0.72–0.97) for measuring the tone, stiffness, and elasticity of the biceps brachii, triceps brachii, deltoid, and upper trapezius muscles. The ICC values obtained indicated that the MyotonPRO has sufficient reliability to measure the tone, stiffness, and elasticity of muscles in chronic stroke patients^{18,19}. In addition, CV values were below 11% in all assessed parameters. A CV value of less than 15% is allowed for measuring biological material. Furthermore, Bland-Altman analysis, which was used to identify potential systematic bias between measurements. The Bland-Altman analysis results showed that there was no systematic bias for all the muscles assessed, which showed consistency between the two measurements performed.

There are a few studies which investigated the inter-rater reliability of myotonometers in stroke patients. Chuang et al.¹⁴ investigated the intra-rater reliability of the Myoton-3 myometer, which is a previous version of the MyotonPRO. They reported that Myoton 3 has good to excellent reliability (ICC: 0.72–0.96) for measuring the tone, elasticity, and stiffness of the biceps brachii and triceps brachii muscles¹⁴. Moreover, Chuang et al.¹³ indicated that the Myoton-3 myometer had excellent intra-rater reliability (ICC: 0.83–0.95) for measuring the tone, stiffness, and elasticity of the deltoid, triceps brachii, biceps brachii, extensor digitorum, flexor carpi radialis, and flexor carpi ulnaris muscles in stroke patients. In a different study by Chuang et al.¹⁰, it was reported that the Myoton-3 myometer is a reliable device for measuring the tone, elasticity, and stiffness of the triceps brachii and bilateral biceps muscles in patients with subacute stroke, with a good to excellent intra-rater reliability (ICC: 0.72–0.96). Furthermore, Lo et al.¹² assessed the between-days reliability of the MyotonPRO for measuring the tone of the biceps brachii, brachioradialis, rectus femoris, and tibialis anterior muscles in acute stroke patients. They performed the measurement on two consecutive days to detect the between-days reliability of the MyotonPRO. They found that the MyotonPRO had a good to excellent reliability (ICC: 0.81–0.82) corresponding to SEM less than 1.24 Hz, and smallest real difference less than 3.08 Hz¹². Lo et al.¹¹ investigated the inter-rater reliability of the MyotonPro for measuring the tone, stiffness, and elasticity of the biceps brachii, brachioradialis, rectus femoris, and tibialis anterior. They found a good to excellent inter-rater reliability in measuring the muscle mechanical properties (ICC: 0.63–0.97)¹¹. There is a consensus in studies regarding the reliability of myotonometers. There seems to be a consensus in the literature that myotonometers are a reliable tool for measuring muscle mechanical properties; however, some of these studies investigated the intra-rater reliability of the Myoton-3 myometer^{10,13,14}, and some of them included patients with acute stroke^{10–12}. The results of the present study, which support the results of the studies in the literature, indicated that the MyotonPRO is a reliable tool also in patients with chronic stroke.

The present study has some limitations. Firstly, the present study was conducted in stroke patients with mild or moderate spasticity to be able to place them in a suitable measuring position. The results of the reliability assessment of the MyotonPRO would be different in patients with severe spasticity. Second, the measurements were performed in a rest state. The reliability of the device may be different in muscle contracted conditions or in a tension state. Lastly, the reliability of the MyotonPRO in stroke patients was investigated in superficial and larger skeletal muscles. Further studies regarding the reliability of the MyotonPRO in small muscle groups, muscle contracted conditions, or tension states in patients with chronic stroke are warranted.

Conclusion

The results obtained show that the MyotonPRO has a good to excellent intra-rater and inter-rater reliability for measuring the tone, stiffness, and elasticity of the deltoid, biceps brachii, triceps brachii, and upper trapezius muscles in patients with chronic stroke. The findings demonstrated that the MyotonPRO is a reliable and repeatable tool for quantifying the muscle mechanical properties in stroke patients. The MyotonPRO can be used for the diagnostic and therapeutic intentions.

Practical implications.

- Inter-observer reliability of MyotonPRO ranged from good to excellent.
- Inter-day reliability of MyotonPRO ranged from good to excellent.
- Coefficient of variation values were in a range from 3.9–11.0%.
- MyotonPRO is a repeatable tool to quantify the muscle mechanical properties.

Declarations

Conflict of Interest Disclosure: None

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data Availability

All data included in this study are available upon request by contact with the corresponding author.

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Author contributions

S.T., M.T.T, F.D., and A.A. designed experiments; S.T., M.T.T, F.D., and A.A. wrote the main manuscript text; A.A and M.T.T performed experiments; S.T. and A.A. analyzed data; S.T. performed figures, S.T. supervised paper. All authors reviewed the manuscript.

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Tables

Table 1. Demographic and clinical characteristics of the stroke patients.

Characteristic	Mean±SD	Minimum-Maximum
Age (years)	65.1±11.2	36-84
Height (meter)	1.70±0.09	1.55-1.90
Mass (kilogram)	73.5±9.6	56-91
Body Mass Index (kg/m ²)	25.4±2.6	19.8-29.4
Disease duration (month)	9.7±3.3	6-17
Gender		
Male		14 (70 %)
Female		6 (30 %)
Spasticity (no/yes)		10/10
Dominant hand		
Right		19 (95 %)
Left		1 (5 %)
Side of stroke		
Right		9 (45 %)
Left		11 (55 %)

Table 2. Inter-rater Reliability Results

	Rater 1	Rater 2	ICC (%95 CI)	CV (%)	SEM	MDC
Biceps brachii muscle						
Frequency (Hz)	12.4±2.9	12.9±2.9	0.78 (0.47-0.91)	9.7	1.2	3.4
Stiffness (N/m)	221.2±35.9	221.1±34.5	0.90 (0.74-0.96)	4.8	10.6	29.3
Decrement	1.9±0.5	1.9±0.6	0.85 (0.62-0.94)	9.7	0.2	0.5
Triceps brachii muscle						
Frequency (Hz)	11.8±2.1	11.8±2.0	0.76 (0.39-0.91)	7.4	0.9	2.4
Stiffness (N/m)	237.8±37.7	238.2±30.1	0.92 (0.79-0.97)	3.9	9.2	25.6
Decrement	2.1±0.5	2.1±0.4	0.75 (0.34-0.90)	9.6	0.4	0.6
Deltoid muscle						
Frequency (Hz)	15.2±1.9	15.1±2.0	0.85 (0.62-0.94)	4.8	0.7	2.0
Stiffness (N/m)	295.6±54.5	298.8±45.7	0.85 (0.60-0.94)	6.1	18.1	50.1
Decrement	1.7±0.4	1.8±0.4	0.86 (0.63-0.94)	8.5	0.2	0.4
Upper trapezius muscle						
Frequency (Hz)	17.3±2.0	17.6±2.4	0.81 (0.47-0.92)	3.4	0.6	1.7
Stiffness (N/m)	300.8±45.6	319.32±59.64	0.82 (0.53-0.93)	6.8	21.0	58.3
Decrement	1.2±0.1	1.2±0.2	0.74 (0.36-0.90)	6.7	0.1	0.2

Table 3. Inter-day Reliability Results

	Testing time point 1	Testing time point 2	ICC (%95 CI)	CV (%)	SEM	MDC
Biceps brachii muscle						
Frequency (Hz)	12.4±2.9	12.9±2.6	0.97 (0.92- 0.99)	3.8	0.5	1.3
Stiffness (N/m)	221.2±35.9	217.7±40.5	0.92 (0.79- 0.97)	4.7	10.3	28.7
Decrement	1.9±0.5	1.7±0.4	0.72 (0.27- 0.89)	11.0	0.2	0.5
Triceps brachii muscle						
Frequency (Hz)	11.8±2.1	11.8±2.0	0.92 (0.78- 0.97)	6.2	0.7	2.3
Stiffness (N/m)	237.8±37.7	237.6±35.3	0.93 (0.82- 0.97)	4.0	9.4	25.4
Decrement	2.1±0.5	2.1±0.5	0.88 (0.69- 0.95)	8.0	0.2	0.5
Deltoid muscle						
Frequency (Hz)	15.2±1.9	15.2±1.8	0.83 (0.54- 0.94)	4.1	0.6	1.7
Stiffness (N/m)	295.6±54.5	290.4±45.9	0.74 (0.31- 0.90)	7.4	21.2	59.1
Decrement	1.7±0.4	1.7±0.4	0.78 (0.42- 0.92)	9.8	0.2	0.5
Upper trapezius muscle						
Frequency (Hz)	17.3±2.0	16.7±1.7	0.82 (0.54- 0.93)	3.8	0.6	1.8
Stiffness (N/m)	300.8±45.6	292.0±43.4	0.81 (0.51- 0.93)	5.6	16.4	45.4
Decrement	1.2±0.1	1.2±0.1	0.91 (0.78- 0.97)	3.2	0.1	0.1

Figures

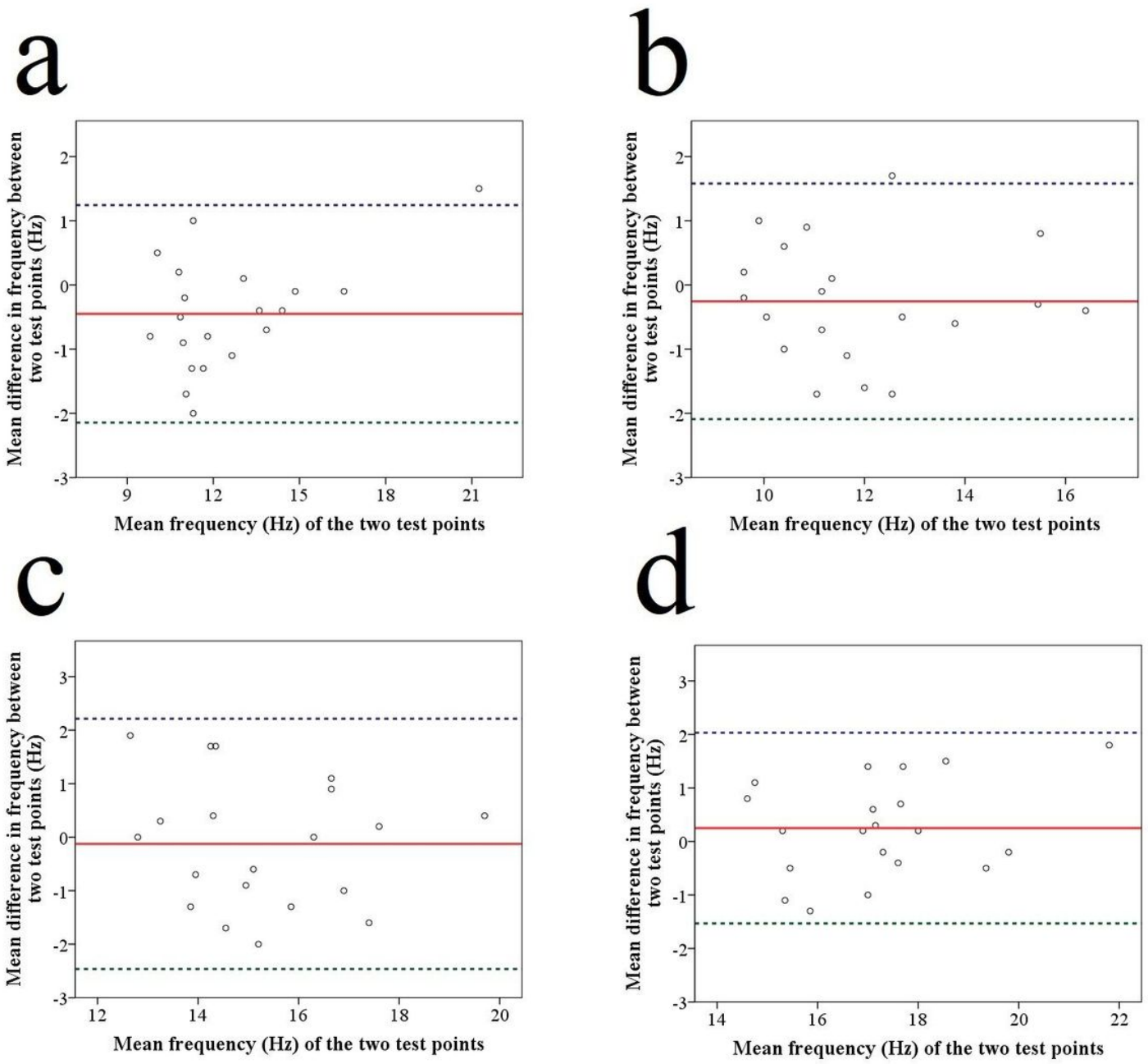


Figure 1

Bland and Altman plots of the inter-rater reliability of the biceps brachii (a), triceps brachii (b), deltoid (c), and upper trapezius muscles (d).

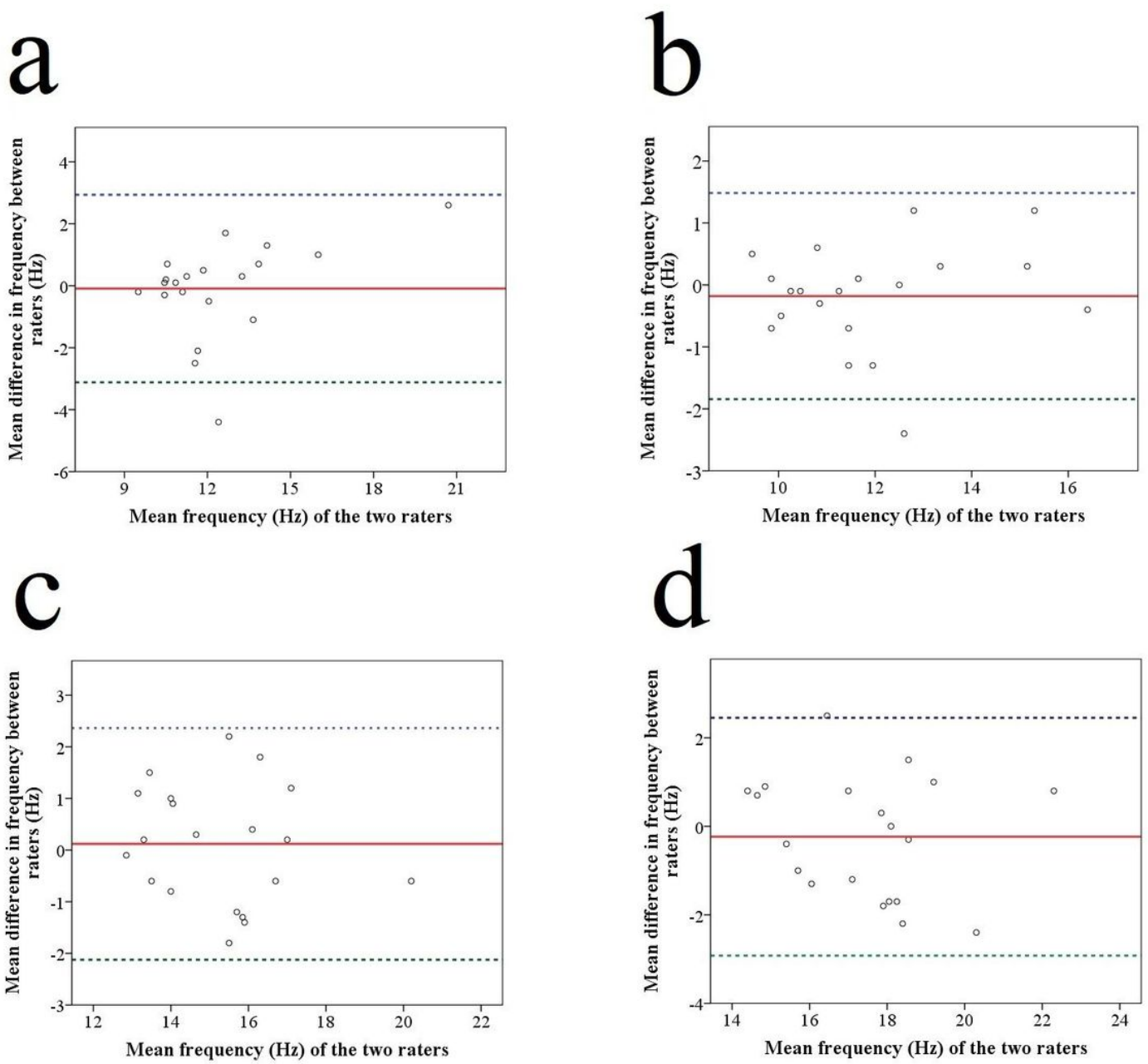


Figure 2

Bland and Altman plots of the intra-rater reliability of the biceps brachii (a), triceps brachii (b), deltoid (c), and upper trapezius muscles (d).