
**P-ISSN:** 2394-1685
**E-ISSN:** 2394-1693
Impact Factor (RJIF): 5.38
IJPESH 2023; 10(5): 152-162

www.kheljournal.com
Received: 23-07-2023
Accepted: 27-08-2023

**All Author's Names given below the References**

# The reliability of MyotonPro in assessing the stiffness in lumbar spinal erector muscles and the effect of different position

**Mboutou Burton Calvin, Bouhika Eddie Janvier, Mabounda Kounga Paul Roger, Nsompi Florent, Moussouami Innocent Simplice, Lolo Denove Styven, Xue-Qiang Wang and Mbemba François**

**DOI:** https://doi.org/10.22271/kheljournal.2023.v10.i5c.3087

**Abstract**

**Objective:** The aim of this study was to evaluate the inter-operator and intra-operator reliability of lumbar muscle stiffness assessment for the erector spinal muscle by MyotonPRO at different vertebral levels and at different trunk flexion positions on the left and right sides in healthy people. This study also aimed to explore the differences of muscle stiffness between different test points and between different trunk flexion positions.

**Method:** This study recruited 54 participants aged from18 to 30 years old, including 22 men and 32 women. Two operators used MyotonPRO to evaluate the muscle stiffness of erector spinal muscles at three vertebrae levels (L1, L3 and L5). The assessment for each level was applied during participants keeping at 0° flexion position (natural standing), 30° flexion position, and 60° flexion position. The inter-operator reliability was considered as the assessment results from two operators in the same day, and the intra-operator reliability was calculated by the assessment results from the same operator in two different days with a 7-day interval. The differences of lumbar muscle stiffness between different test points and flexion positions were explore based on the assessment result from one operator. Moreover, the differences of muscle stiffness between difference teat points or different positions were detected by one-way analysis of variance (ANOVA) and post-hoc analysis.

**Results:** Most ICC values for reliability of muscle stiffness assessment were higher than 0.75. In healthy people, the ICC values ranged from 0.719 to 0.940. Those of SEM ranged between 28.23 and 130.31 and those of MDC ranged between 78.24 and 361.20. Furthermore, the ICC values for inter-operator and intra-operator reliability on the right side were L1 (0.915, 0.846); L3 (0.865, 0.859) and L5 (0.908, 0.845) at neutral 0° flexion position; L1 (0.924, 0.926), L3 (0.925, 0.902) and L5 (0.916, 0.881) at 30° flexion position; L1 (0.897, 0.893); L3 (0.826, 0.835) and L5 (0.902, 0.785) at 60° flexion position. In terms of the effect of test points on the muscle stiffness, we found significant differences between L1, L3, and L5 in healthy people. The muscles stiffness of L1 was significantly lower than that of L3 and L5 at left and right sides at 0°, 30° and 60° flexion in two populations ($p<0.05$). Whereas patients performed higher muscle stiffness on other points at other positions as well but without any significances.

**Conclusion:** The intra-operator and inter-operator reliability of muscle stiffness are basically good to outstanding regardless of different test points and positions in healthy people, which means using MyotonPRO is a reliable way to assess the lumbar muscle stiffness at multiple levels and position in different population. Generally, lumbar muscle stiffness increases in order L1, L3 and L5 in all flexion positions, which might be caused the anatomical feature of muscles. In future, more research studies including a large sample size and focusing on the relationships between lumbar muscle stiffness.

**Keywords:** Muscle stiffness, reliability; MyotoPro, position, low back pain

## Introduction

Low back pain (LBP) is one of the most common disorders and represents a substantial economic burden on society [1]. Most patients have suffered from low back pain for more than a year and only 25% recover completely without disability [2]. More than 70% of adults suffer from LBP at least once in their life [3].

**Corresponding Author:**
**Bouhika Eddie Janvier**
1. Unité de Recherche de Nutrition, Santé et Motricité Humaine, Institut Supérieur d'Education Physique et Sportive. Université Marien NGOUABI, Brazzaville, BP: 69, République du Congo
2. Laboratory of Education, Health, Expertise and Optimization of Human Performance, High Institute of Physical and Sports Education (ISEPS), Marien Ngouabi University; Po Box 69, Brazzaville, Republic of Congo

So, the lumbar spine muscle or the spinous erector muscles have an action of extension, flexion, and rotation of the trunk. In general, the muscle is effectively stretched in positions opposite to the direction of muscle action. In rehabilitation, the lumbar erector muscle of the spine is frequently stretched in a flexed position of the trunk [4, 5].

An accurate path anatomic diagnosis is only possible in 15% of patients with LBP. Several studies have shown that a decrease in core muscle strength and an increase or decrease in the angle of lumbar lordosis is linked to chronic low back pain (CLBP) [6, 7]. An excessive load to the intervertebral disc may occur due to an increased or decreased lumbar dose angle. The joint, our intervertebral disc, causes a painful deterioration of the lower back [8, 9]. The deviation of the normal lumbar lordosis angle may play a significant role in lower back pain, according to this analysis [10]. The paraspinal lumbar muscles are important flexors and stabilizers in the spine, and dysfunction of these muscles is associated with LBP [11]. While performing dynamic movements and static positions, the loss of lumbar paraspinal muscle weakness can result in a lack of spinal function. In order to determine the effects of neural muscle properties on subjects with low back pain and other types of musculoskeletal disorders, LBP exercises have been focusing on abdominal stabilization and contraction by flexing in different degrees [12, 13].

Several studies have shown that in patients with ankylosing spondylitis, extensor lumbar stiffness or myofascial is greater than in healthy subjects of the same age, and the elasticity of lumbar extensor myofascia is lower in patients with ankylosing spondylitis than in healthy subjects of the same age [14, 15]. For adolescent patients with chronic low back pain, some studies have also quantitatively analysed muscle tone and stiffness of the lumbar and dorsal fascia [16, 17]. Although chronic low back pain is more commonly diagnosed in younger people, it is still diagnosed mainly in the elderly. While manual palpation is mainly used for assessing the biomechanical properties of lumbar extensor myofascia and paraspinal muscles and fascia, it can also be beneficial to diagnose and assess effects [18, 19]. Nevertheless, the reliability of automatic palpation in clinical use has been questioned for some time [20, 21]. Due to their high costs and impracticality of operation, advanced test methods such as ultrasound or magnetic resonance elastography are not always feasible [22, 23]. As a result, it has been challenging to clinically measure the biomechanical characteristics of muscle tissue. A portable muscle sensor called MyotonPRO monitors the tone, suppleness, and stiffness of muscles and myofascial tissues without using any force [17].

The biomechanical characteristics of skeletal muscles, particularly the gastrocnemius and upper trapezius muscles, were measured in earlier investigations using MyotonPRO [24, 25]. More notably, they discovered a strong correlation between the shear modulus assessed by shear wave elastography and the stiffness of the gastrocnemius muscle and Achilles tendon, as measured by MyotonPRO [26]. This demonstrated a good validity of MyotonPRO in assessing muscle stiffness. Furthermore, previous studies also reported the reliability of some specific muscle stiffness assessment using MyotonPRO, such as gastrocnemius, masseter and lumbar spinal erectormuscle. However, most of them only focused on the one body position during assessment, such as prone or sitting position. It is still unclear how the muscle stiffness and reliability of stiffness test changes when using MyotonPRO to assessing the spinal muscles in different positions. Therefore, the aim of this present study was to evaluate the reliability of MyotonPRO when assessing the muscle stiffness of lumbar spinal erector at different points and in different positions, and explore the differences of muscle stiffness of lumbar spinal erector between different sides, points, and body positions.

## Method

### Research object

According to the sample size calculation method described in previous research on sample size and reliability optimization design, calculate the estimated sample size of three repeated measurement hardness tests. Each test was repeated three times for each subject, i.e. n = 3, assuming α= 0.05 and power = 80% (intraclass correlation efficiency, ICC), p1 (ICC) = 0.8, p0 (ICC) = 0.6, p represents the calculated reliability ICC value, p0 refers to the lowest acceptable reliability level, p1 refers to the level with higher reliability than p0, and the calculated sample size is 27. 54 subjects are actually included in this test. Fifthen four participants (22 men and 32 women) were recruited from Shanghai University of Sport. Digital muscle state detection and evaluation at Shanghai University of Sport. All participants were informed and consented to the content of the experiment.

Obeying the following inclusion criteria: 1) Be in good health (no musculoskeletal disease, no back pain); 2) be between 18 and 30 years old; 3) be physically active; doing regular physical exercises; 4) be willing to finish the study, that is say to have the whole experience.

### Procedure

All measurements were made in the same space, which was about 25 °C warm. A certified physiotherapist affixes measuring marks to gastrocnemius muscle and Achilles tendons, in order to reduce the error of measurements. Participants were then instructed to stand with their feet on either side of a defined location on the floor and assume a comfortable standing position that felt natural to them before the angles of the spine were measured. From each marker site, three angles were measured. Palpation was used to identify the spinous processes of the L1, L3, and L5 vertebrae, which were then marked with dots on the target vertebrae.

Participants stand naturally then dorso-flex at different degrees 30 ° and 60 ° from the vertical axis of the initial position of the hip joint. We limited the participant's forward flexion angle with an articometer. in the experiment was an improved square plate measuring instrument designed by Shanghai Huashan Hospital in 1974 [27]. The pointer in the center of the measuring instrument always points to the top because the center of gravity is below. When using, the limbs at both ends of the joint are on the same vertical plane, and one limb is in a horizontal or vertical position, and one side of the square plate is close to the other limb. When the surface is on the same vertical plane as the limb, the angle of the joint can be read. Compared with the traditional semicircular protractor, the activity measuring instrument can be compared with the traditional semicircular protractor without touching the bony signs, the operation is fast and convenient, and the error is small, and at the same time, the shortcoming that the axis of the semicircular protractor deviates from the functional axis of the joint is avoided. Research confirms that the protractor can be used to measure joint movement in the spine and limbs [27]. We put the joint activity measuring instrument close to the spinous process of the third lumbar vertebra. The pointer of the movable ruler is parallel to the spine. The movable ruler will increase as the patient's flexion angle increases. When the pointer points to 30°, the patient stops flexion and maintains the pose. Participants flexed 60° in the same way as in 30°.

The subjects rested and relaxed for 5min before hardness measurement. When the participant is in the prescribed position, the evaluator holds the digital muscle state detector MyotonPRO (MyotonAS, Estonia) with the wrist in the air, without any body part contact with the participant. The MyotonPRO probe vertically and lightly on the skin surface of 1.5cm next to the spinous process of the first lumbar vertebra, and the average value was taken. The measurement steps for the third lumbar paraspinal muscle group and the fifth lumbar paraspinal muscle group are the same as those for the first lumbar paraspinal muscle group. Both sides left and right paraspinal muscle groups were measured. When all six measurement points in one position were completed, the participants rested for 5 minutes for the measurement of the next position.

When the tester is not moving, the tester will send a mechanical pulse. After the measurement is completed, 5 measurement result parameters will be displayed on the screen and the soft tissue oscillation acceleration curve can be viewed at the same time. This measurement adopts the three-sweep mode, i.e. the same measuring point receives 3 pulses continuously, and the average value is used as the measurement result. The probe impact time is 15ms, the interval is 0.8s, and the delay is 0.7s. If the coefficient of variation (CV) > 3%, re measure.

Data collection for the same participant was carried out in two phases. Two experienced operators A and B. In the first phase, after the first assessor (A) has assessed the paraspinal muscle groups in all positions, the participant rests for five (5) minutes and the second assessor (B) measures again on the same day. A second phase was performed 7 days after the first intervention, with operators (A) and (B) repeating the same procedure. Both assessors A and B were trained in the use of MyotonPRO in a formal training course. Using this process, 30 healthy people and 30 patients with chronic low back pain were tested for the muscle stiffness of the left and right L1, L3, L5 paraspinal muscles under the natural standing and forward flexion of 30° and 60°.

The threshold of sensitivity and physical parameters was performed immediately. The specific test indicators are as follows: The unit of dynamic stiffness (S) is N / m. Measurements of the biometric properties of tissues shall be shown in D=0 and S=0 values. The effectiveness of the exercise will be greatly reduced when muscle stiffness rises in a manner that is abnormal and muscular elasticity deteriorates.

## Statistical analyzes

For statistical analysis version 22.0, IBM, Armonk, New York, USA, the SPSS software was used. As a mean SD, the mean and standard deviations of the stiffness values are shown. In order to assess whether data have a normal distribution, the Shapiro Wilk test has been used. Demographics of participants have been estimated using descriptive statistics.

The intra-class correlation coefficients (ICC) were obtained and used to assess the test's reliability using the ICC (2.2) and ICC (3.1) models. The Domholdt scale classified the CCI value as > 0.90, outstanding; 0.75-0.90, good; 0.50-0.75, moderate; and 0.50, bad [28]. The standard error of measurement (SEM) for intra- and inter-rater reliability was used to examine the accuracy of the assessment methods [29]. SEM = SD ×√ (1-ICC), where SD represents the standard deviation of the measured values and ICC represents the data dependability coefficient. The systematic error and level of agreement in intra-operator and inter- operator reliability were indicated through Bland–Altman plots. Furthermore, one-way ANOVA test was applied to detect any differences of muscle stiffness between L1, L3, and L5 at all position, and between 0°, 30°, and 60° at all test points. Post-hoc analysis was used to find the specific differences between distinct test points or flexion positions if the results from ANOVA is significant. The comparison between patients with LBP and healthy people was operated using the independent t test. The p values less than 0.05 will be considered as a significant difference. Finally, Graphpad Prism8 was used to produce the histograms that represented the differences between the groups.

## Results

### Reliability of muscle stiffness test in healthy people

All ICC values for intra-operator and inter-operator reliability of spinal erector muscle stiffness test at L1, L3, and L5 levels at 0°, 30°, and 60° flexion positions in healthy people were illustrated in Table 2. These results state that the ICC values ranged from 0.719 to 0.940. Those of SEM ranged between 28.23 and 130.31 and those of MDC ranged between 78.24 and 361.20. The reliability of the MyotonPRO quantified on the property of spinal erector muscles at levels L1, L3 and L5 at 0° in healthy people, in natural position on the left side states that, the inter-operator ICC of L3 (0.940) and L5 (0.909) were outstanding. However, the values of ICC of inter-operator L1 (0.799), intra-operator L1 (0.801), L3 (0.835), and L5 (0.874) were good. Furthermore, the reliability of the MyotonPRO quantified on the property of the spinal erector muscles at levels L1, L3 and L5 at 30° in healthy people on the left stipulates that, the value of inter-operator ICCs were 0.938 at L1 point and 0.908 at L5 point, which were higher. However, the values of ICC on inter-operator L3 (0.719), intra-operator L1 (0.862), L3 (0.814), and L5 (0.894) intra were high. Meanwhile, the reliability of MyotonPRO quantified on the property of spinal erector muscles at levels L1, L3 and L5 at 60° in healthy people on the left side states that, the intra-operator ICC of L3 (0.918) and inter-operator ICC of L5 (0.938) were higher. However, the values of ICC for inter-operator L1(0.877) and L3 (0.898), and intraoperator L1 (0.822) and L5 (0.878) were high. The reliability of the MyotonPRO quantified on the property of the spinal erector muscles at the L1, L3 and L5 levels at 0° flexion position in healthy people on the right side stipulates that, the value of inter-operator ICCs were 0.915 at L1 point and 0.908 at L5 point, which were higher. However, the values of ICC on inter-operator L3 (0.865), intra-operator L1 (0.846), L3 (0.859), and L5 (0.845) were high. In addition, the reliability of the MyotonPRO quantified on the property of the spinal erector muscles at the L1, L3 and L5 levels at 30° flexion position on the right side in healthy people stipulates that, the ICC values of inter-operator reliability on L1 point (0.924), L3 point (0.925) and L5 point (0.916), and ICC values of intra-operator reliability on L1 point (0.926) and L3 point (0.902) were higher than 0.90. Nevertheless, the value of the ICC for intra-operator reliability on L5 (0.881) was high. Furthermore, The reliability of the MyotonPRO quantified on the property of the spinal erector muscles at the L1, L3 and L5 levels at 60° flexion position on the right side in healthy people stipulates that, the ICC value for inter-operator reliability on L5 point (0.902) was higher. However, the values of ICC for inter-operator L1(0.897) and L3(0.826), for intra-operator L1 (0.893), L3 (0.835) and L5 (0.785) were high.

**Table 1:** Inter-and intra-operator reliability of Erector spinal muscles at L1, L3 and L5 levels at 0, 30 and 60 flexion in healthy people, respectively

| | | Mean ± SD | SEM | MDC | ICC (95% CI) |
|---|---|---|---|---|---|
| | | | | **Left-0** | |
| L1 | A1 | 316.98±98.88 | 44.33 | 122.88 | |
| | B | 315.36±116.31 | 52.15 | 144.55 | Inter-operator: 0.799 (0.619-0.899) |
| | A2 | 326.16±103.34 | 46.10 | 127.78 | Intra-operator: 0.801 (0.626-0.900) |
| L3 | A1 | 671.86±174.41 | 42.72 | 118.42 | |
| | B | 680.11±179.17 | 43.89 | 121.65 | Inter-operator: 0.940 (0.879-0.971) |
| | A2 | 683.61±189.64 | 77.03 | 213.52 | Intra-operator: 0.835 (0.684-0.918) |
| L5 | A1 | 718.72±174.68 | 52.69 | 146.06 | |
| | B | 719.50±163.05 | 49.19 | 136.33 | Inter-operator: 0.909 (0.817-0.955) |
| | A2 | 744.11±181.02 | 64.25 | 178.10 | Intra-operator: 0.874 (0.751-0.938) |
| | | | | **Left-30** | |
| L1 | A1 | 275.79±113.36 | 28.23 | 78.24 | |
| | B | 264.90±127.74 | 31.81 | 88.16 | Inter-operator: 0.938 (0.874-0.970) |
| | A2 | 266.80±119.33 | 44.33 | 122.88 | Intra-operator: 0.862 (0.732-0.932) |
| L3 | A1 | 605.20±227.15 | 120.41 | 333.76 | |
| | B | 635.83±240.78 | 127.64 | 353.79 | Inter-operator: 0.719 (0.492-0.855) |
| | A2 | 640.66±230.05 | 99.22 | 275.01 | Intra-operator: 0.814 (0.647-0.906) |
| L5 | A1 | 711.84±187.96 | 57.01 | 158.03 | |
| | B | 721.49±192.88 | 58.50 | 162.16 | Inter-operator: 0.908 (0.816-0.955) |
| | A2 | 724.54±194.47 | 63.31 | 175.50 | Intra-operator: 0.894 (0.791-0.948) |
| | | | | **Left-60** | |
| L1 | A1 | 240.96±129.01 | 45.24 | 125.41 | |
| | B | 247.91±131.73 | 46.20 | 128.06 | Inter-operator: 0.877 (0.759-0.939) |
| | A2 | 229.27±119.52 | 50.43 | 139.78 | Intra-operator: 0.822 (0.661-0.911) |
| L3 | A1 | 490.40±277.80 | 88.72 | 245.93 | |
| | B | 523.82±277.44 | 88.61 | 245.61 | Inter-operator: 0.898 (0.797-0.950) |
| | A2 | 496.76±268.88 | 77.00 | 213.42 | Intra-operator: 0.918 (0.835-0.960) |
| L5 | A1 | 642.01±307.49 | 76.56 | 212.23 | |
| | B | 642.72±266.90 | 66.46 | 184.21 | Inter-operator: 0.938 (0.874-0.970) |
| | A2 | 603.57±256.04 | 89.43 | 247.89 | Intra-operator: 0.878 (0.761-0.940) |
| | | | | **Right-0** | |
| L1 | A1 | 355.04±144.99 | 42.27 | 117.17 | |
| | B | 362.02±173.03 | 50.45 | 139.83 | Inter-operator: 0.915 (0.830-0.959) |
| | A2 | 347.18±137.00 | 53.76 | 149.02 | Intra-operator: 0.846 (0.703-0.924) |
| L3 | A1 | 699.83±178.29 | 65.51 | 181.57 | |
| | B | 693.14±170.08 | 62.49 | 173.22 | Inter-operator: 0.865 (0.736-0.933) |
| | A2 | 685.17±172.43 | 64.75 | 179.47 | Intra-operator: 0.859 (0.727-0.930) |
| L5 | A1 | 755.78±165.16 | 50.10 | 138.86 | |
| | B | 742.16±166.80 | 50.59 | 140.24 | Inter-operator: 0.908 (0.817-0.955) |
| | A2 | 730.08±158.20 | 62.28 | 172.64 | Intra-operator: 0.845 (0.700-0.923) |
| | | | | **Right-30** | |
| L1 | A1 | 309.61±156.55 | 43.16 | 119.63 | |
| | B | 316.90±162.72 | 44.86 | 124.34 | Inter-operator: 0.924 (0.848-0.963) |
| | A2 | 305.14±145.81 | 39.66 | 109.94 | Intra-operator: 0.926 (0.851-0.964) |
| L3 | A1 | 659.76±214.15 | 58.65 | 162.56 | |
| | B | 677.70±219.88 | 60.22 | 166.91 | Inter-operator: 0.925 (0.850-0.964) |
| | A2 | 646.07±212.39 | 66.49 | 184.29 | Intra-operator: 0.902 (0.805-0.952) |
| L5 | A1 | 743.43±185.38 | 53.73 | 148.92 | |
| | B | 752.20±188.21 | 54.55 | 151.20 | Inter-operator: 0.916 (0.832-0.959) |
| | A2 | 732.98±187.72 | 64.76 | 179.50 | Intra-operator: 0.881 (0.767-0.942) |
| | | | | **Right-60** | |
| L1 | A1 | 244.61±120.74 | 38.75 | 107.41 | |
| | B | 270.14±123.98 | 39.79 | 110.29 | Inter-operator: 0.897 (0.759-0.953) |
| | A2 | 242.20±123.44 | 40.38 | 111.92 | Intra-operator: 0.893 (0.787-0.947) |
| L3 | A1 | 539.59±312.39 | 130.31 | 361.20 | |
| | B | 586.83±271.54 | 113.27 | 313.96 | Inter-operator: 0.826 (0.667-0.913) |
| | A2 | 551.69±302.04 | 122.69 | 340.08 | Intra-operator: 0.835 (0.682-0.918) |
| L5 | A1 | 655.50±256.17 | 80.19 | 222.29 | |
| | B | 688.33±249.25 | 78.03 | 216.28 | Inter-operator: 0.902 (0.803-0.952) |
| | A2 | 625.32±231.18 | 107.19 | 297.13 | Intra-operator: 0.785 (0.599-0.891) |

Notes: ICC, intraclass correlation coefficients; CI, confidence interval; SEM (N/m), the standard error of measurement; MDC (N/m), the minimal detectable change; A1, operator A first test; B, operator B; A2, operator A second test; 0, 30 and 60, representing at 0°, 30° and 60° flexion position, respectively.

In addition, Figures 1-6 indicate that the BlandAltman models for intraoperator and interoperator reliabilities to measure ES muscle stiffness across different locations in healthy subjects have been shown. For the left test points at the 0° flexion position in healthy people, the maximal mean difference was found in the intra-operator reliability on L5, with −25.4, while the minimal mean difference was observed in the inter-operator reliability on L5, with −0.8 (Figure 1). For the left test points at the 30° flexion position in healthy people, the maximal mean difference was found in the inter-operator reliability on L3, with −30.6, while the minimal mean difference was observed in the intra-operator reliability on L1, with −9.0 (Figure 2). For the left test points at the 60° flexion position in healthy people, the maximal mean difference was found in the intra-operator reliability on L5, with 38.4, while the minimal mean difference was observed in the inter-operator reliability on L5, with −0.7 (Figure 3). With regards to the right side, the maximal mean difference was found in the intra-operator reliability on L5, with 25.7, while the minimal mean difference was observed in the inter-operator reliability on L3, with 6.9, when healthy people keeping the 0° flexion position (Figure 4). The maximal mean difference was found in the inter-operator reliability on L3, with −17.9, while the minimal mean difference was observed in the intra-operator reliability on L1, with 4.5, when healthy people keeping the 30° flexion position (Figure 5). The maximal mean difference was found in the inter-operator reliability on L3, with −47.2, while the minimal mean difference was observed in the intra-operator reliability on L1, with 2.4, when healthy people keeping the 60° flexion position (Figure 6).

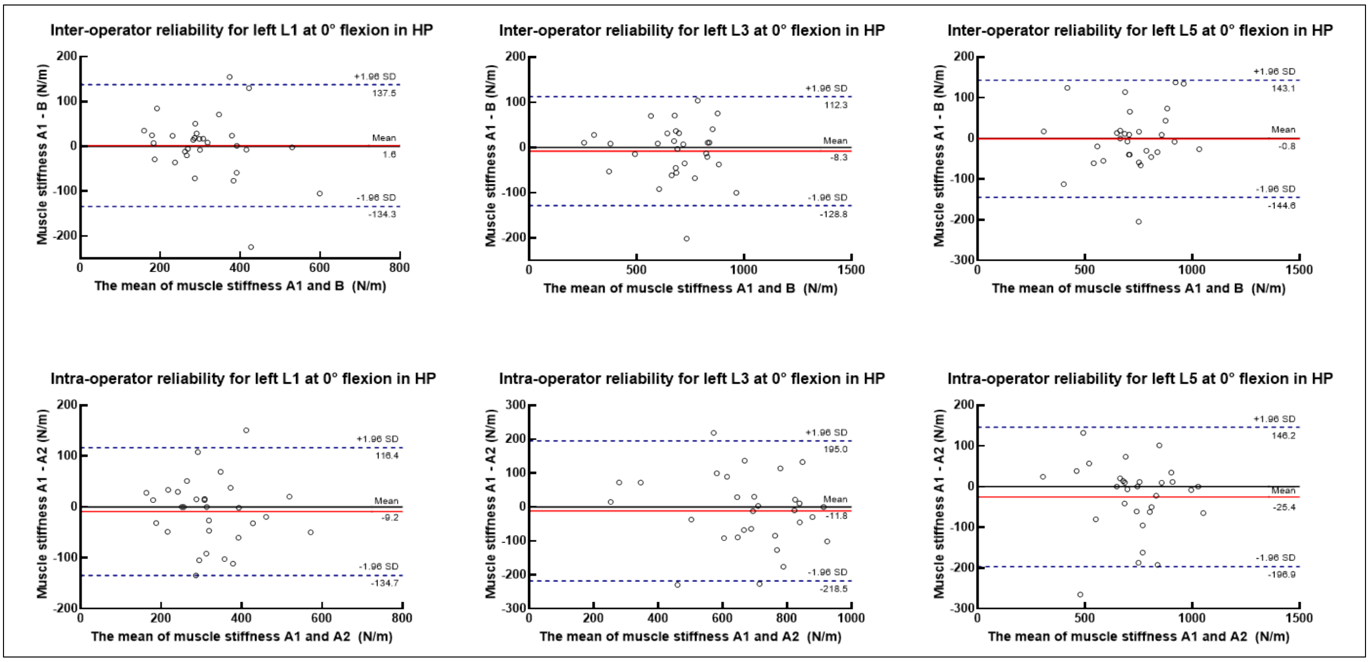


**Fig 1:** Bland-Altman plots of intra-operator and inter-operator reliabilities for assessing muscle stiffness of left ES at natural position 0° in healthy people.

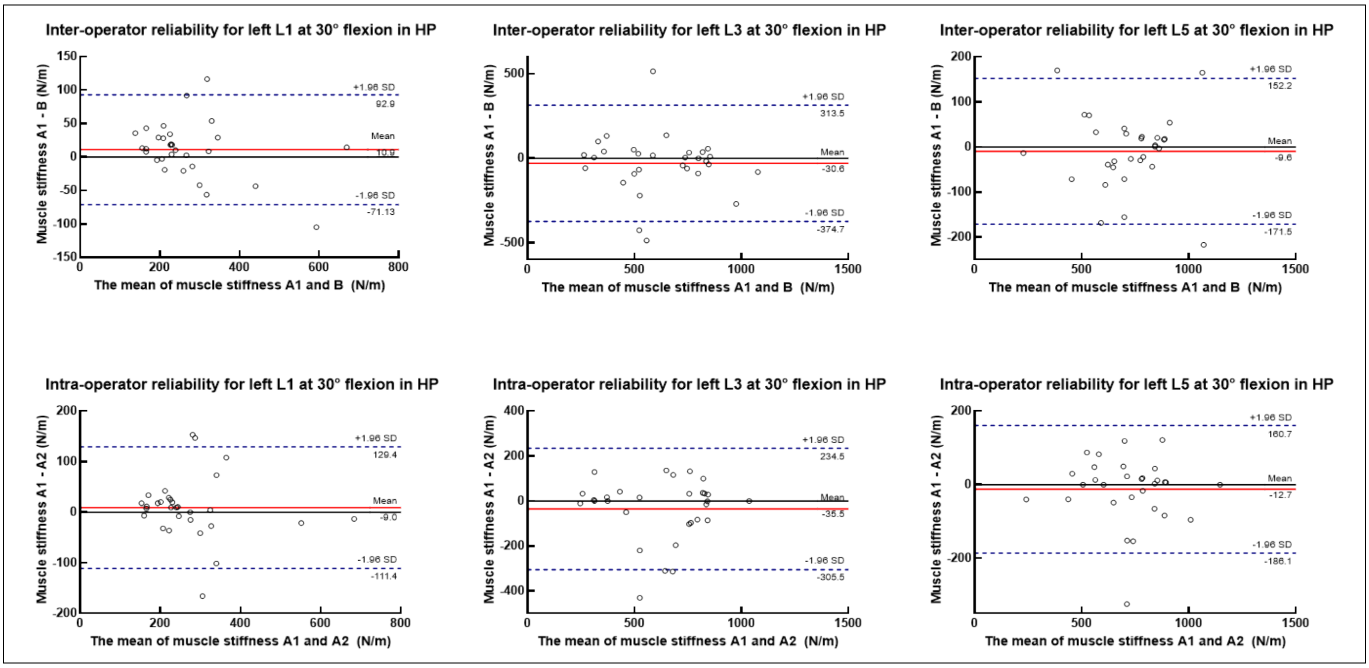


**Fig 2:** Bland-Altman plots of intra-operator and inter-operator reliabilities for assessing muscle stiffness of left ES at flexion 30°in healthy people.

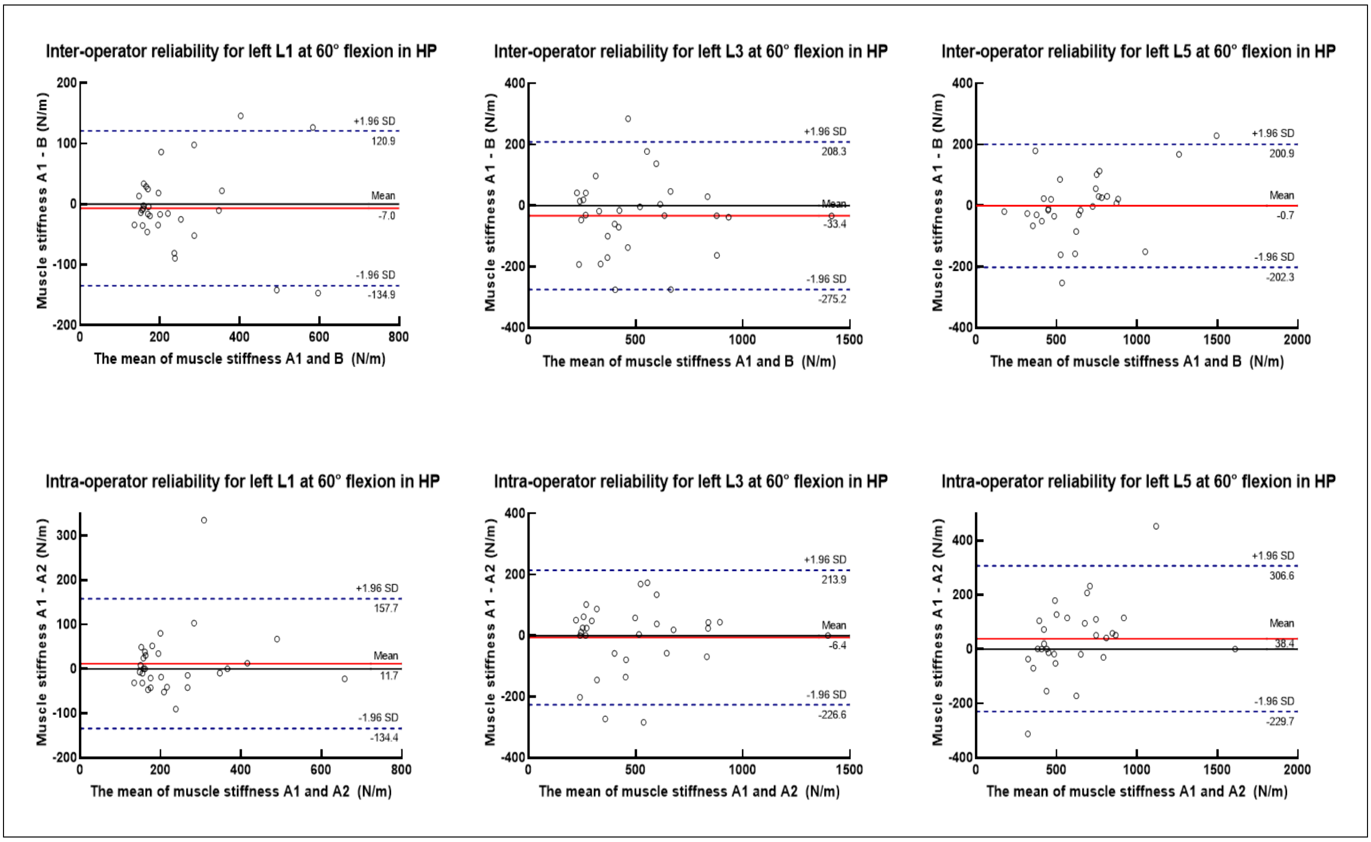


**Fig 3:** Bland-Altman plots of intra-operator and inter-operator reliabilities for assessing muscle stiffness of left ES at flexion 60° in healthy people.

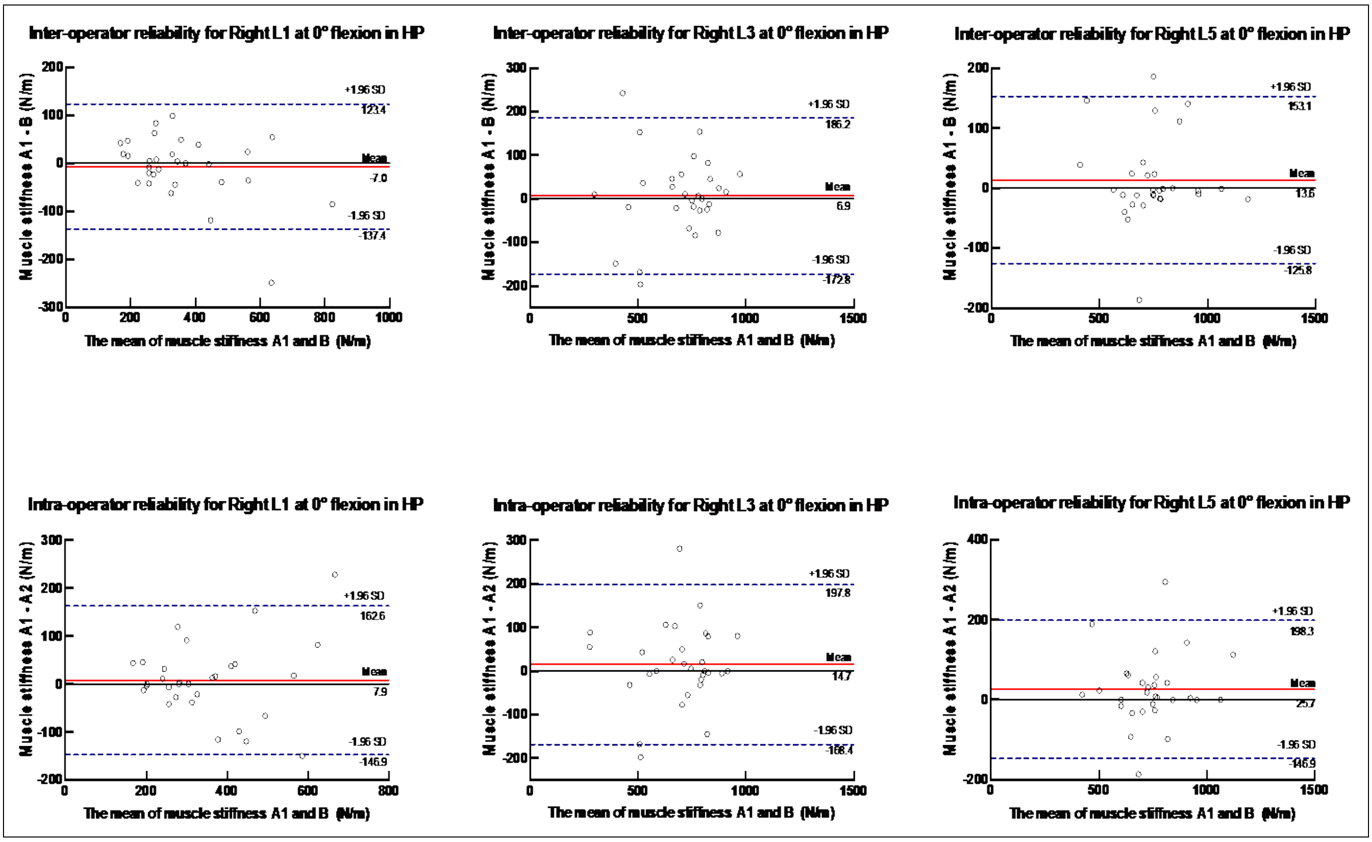


**Fig 4:** Bland-Altman plots of intra-operator and inter-operator reliabilities for assessing muscle stiffness of right ES at natural position 0° in healthy people.

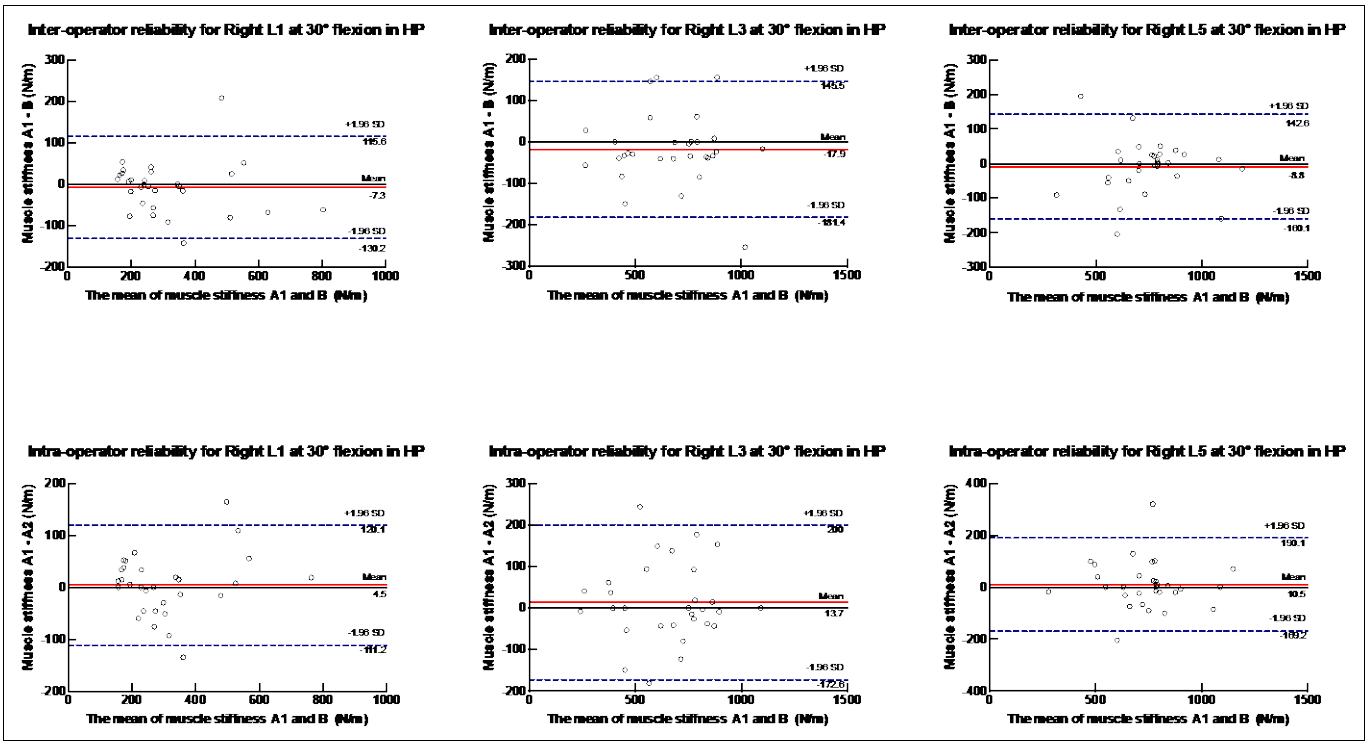


**Fig 5:** Bland-Altman plots of intra-operator and inter-operator reliabilities for assessing muscle stiffness of right ES at flexion 30° in healthy people.

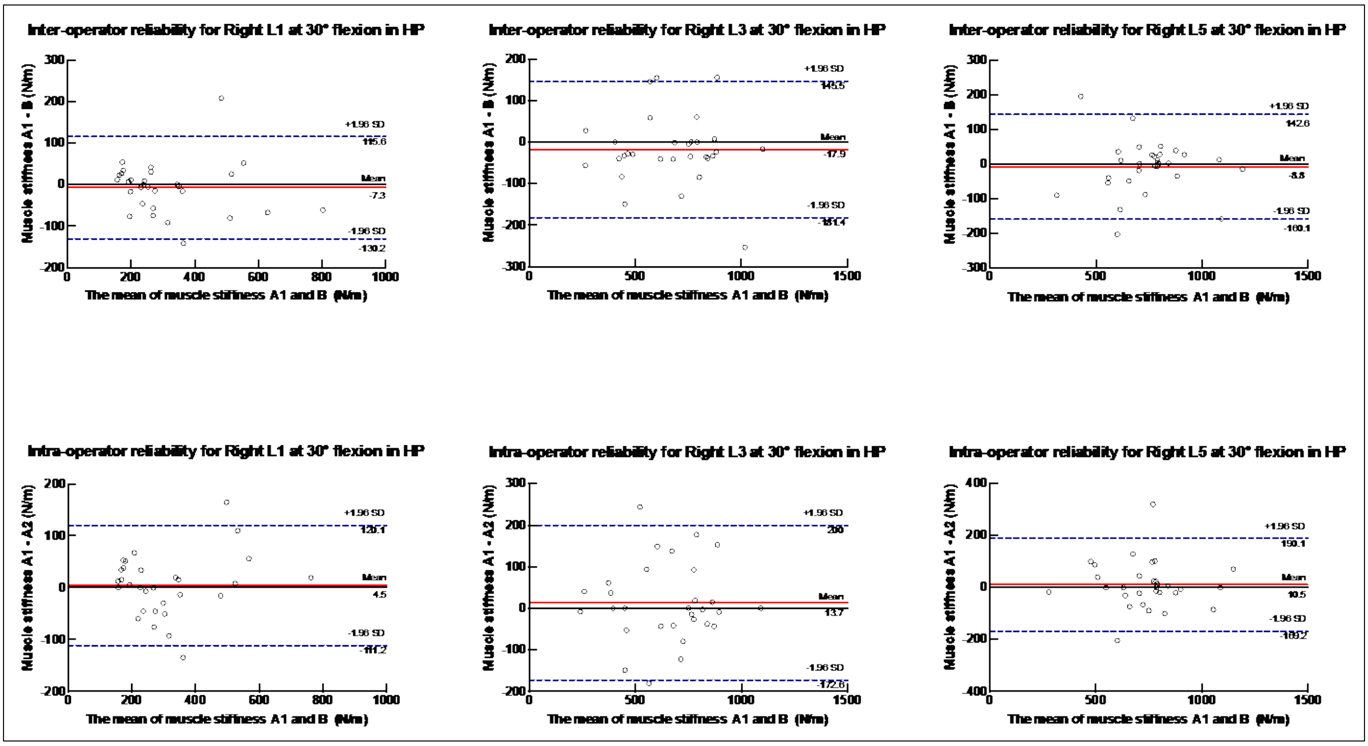


**Fig 6:** Bland-Altman plots of intra-operator and inter-operator reliabilities for assessing muscle stiffness of right ES at flexion 60° in healthy people.

**Difference between distinct points, positions and populations**

Table 4 shows that in healthy subjects, the difference between muscle stiffness of ES L1, ES L3, and ES L5 when they are naturally at 0° flexion, 30° or 60° flexion has been shown to be considerable. By observing the differences between L1 and L3, L1 and L5, and L3 and L5 in healthy people on the left, the difference between L1 and L3, between L1 and L5 at all positions shows that are highly significant and whose ***$p<$ 0.001. However, the difference between muscle stiffness on L3 and L5 at all positions are not significant with* $p< 0.05$. The differences between L1 and L3, L1 and L5 on the right side in healthy people were observed to be very significant, which is also evidenced by an ***p0.001 difference of muscle stiffness at all positions. In case of natural position 0°, in 30° or 60° extension positions there are no significant differences between L3 and L5.

**Table 2:** Difference of Erector Spinal muscle stiffness at different region of lumbar spinal

| | L1 | L3 | L5 | p values | | |
|---|---|---|---|---|---|---|
| | | | | L1 vs L3 | L1 vs L5 | L3 vs L5 |
| **HP at Left** | | | | | | |
| 0 | 316.98±98.88 | 671.86±174.41 | 718.72±174.68 | 0.000 | 0.000 | 0.467 |
| 30 | 275.79±113.36 | 605.20±227.15 | 711.84±187.96 | 0.000 | 0.000 | 0.066 |
| 60 | 240.96±129.01 | 490.40±277.80 | 642.01±307.49 | 0.001 | 0.000 | 0.055 |
| **HP at Right** | | | | | | |
| 0 | 355.04±144.99 | 699.83±178.29 | 755.78±165.16 | 0.000 | 0.000 | 0.385 |
| 30 | 309.61±156.55 | 659.76±214.15 | 743.43±185.38 | 0.000 | 0.000 | 0.198 |
| 60 | 244.61±120.74 | 539.59±312.39 | 655.50±256.17 | 0.000 | 0.000 | 0.161 |

HP= healthy people; ES=Erector spinalis; $^{*}p<0.05$; $^{**}p<0.01$; $^{***}p<0.001$.

## Discussion

This research was carried out primarily in order to assess the reliability of MyotonPRO during the assessment of the lumbar erector spinal muscles on the different spinal vertebrae (L1, L3 and L5), at different positions (0°, 30° and 60°). The study explored the inter- and intra-operator reliability by measuring muscle properties of erectors spinal in healthy people using MyotonPRO. The second purpose of this research was to evaluate the differences of muscle stiffness in healthy people between muscle stiffness on the different spinal vertebrae (L1, L3 and L5), and between muscle stiffness at different positions (0°, 30° and 60°). Our starting hypothesis was that the MyotonPRO is effective in the diagnosis of muscle rigidity and there were differences between different test points, different flexion positions. The findings of the muscle stiffness evaluation on healthy persons will be discussed in this chapter.

## Reliability in healthy people

The values of the ICC in inter-and intra-operator reliability of the erector spinal muscles in L1, L3 and L5 in healthy people in the natural position varied between 0.719 and 0.940 on the left. These natural position results (0°) showed that the ICC values were high, with the good to outstanding inter-operator and intra-operator reliability, L1 (0.799, 0.801); L3 (0.940, 0.835) and L5 (0.909, 0.874). At 30° flexion position, our results stipulated that the values of the ICC were high, which is good to outstanding reliability, except for inter-operator reliability of L3 point, with inter and intra L1 (0.938, 0.862), L3 (0.719, 0.814) and L5 (0.908, 0.894), respectively. In addition, the values of the ICC of our healthy subjects were very high at 60° flexion position varied between (0.822; 0.938), which are good to outstanding, after the evaluation of the Spinal Erector muscle by the MyotonPRO, with the inter-operator and intra-operator L1 (0.877, 0.822); L3 (0.898, 0.918) and L5 (0.938, 0.878). Regarding to the right side, the results of this study showed the values of the ICC inter- and intra-operator reliability of the erector spinal muscles at L1, L3 and L5 levels in healthy people varied between 0.785 and 0.926. In natural position (0°), our results were noted that the ICC values were very high, which shows good to outstanding reliability, with the inter and intra L1 (0.915, 0.846); L3 (0.865, 0.859) and L5 (0.908, 0.845). Similarly, at 30° flexion position the values of the ICC were as high, ranged from 0.881 to 0.926, with inter and intra L1 (0.924, 0.926), L3 (0.925, 0.902) and L5 (0.916, 0.881), respectively. This indicated outstanding inter-operator and intra-operator reliability except for that on intra-operator L5, which is good. Furthermore, the values of the ICC were very high at 60° flexion position after the evaluation of the erector spinal muscle by the MyotonPRO, with the inter and intra L1 (0.897, 0.893), L3 (0.826, 0.835) and L5 (0.902, 0.785). That is to say, the inter-operator and intra-operator reliability for muscle stiffness testing when healthy people performing 60° flexion position is still good to outstanding.

This elevation of reliability of muscle stiffness test at different flexion positions in healthy people indicated a good to outstanding results. This can be explained by the fact that the healthy people were well bearing and had no muscular problem. Starting from this, we can say that the MyotonPRO has been reliable in the assessment of muscle rigidity. For this purpose, Vandeun and al. (2018), had found moderate and high rigidity for both tone on the brachial biceps in the elderly paratonia. This study had shown the reliability of MyotonPRO to the extent of the rigidity of the muscles studied [29]. According to Li-Lingchuang and al. (2012), the MyotonPRO was employed as a reliable, valid, and responsive instrument to objectively evaluate muscular tone, elasticity, and stiffness of the forearm muscles at rest in stroke patients. Because the MyotonPRO's mechanical characterization of skeletal muscle has offered fresh information on muscle functions that can be used to diagnose and treat muscle physiopathology [30]. In addition, a recent study demonstrated that the MyotonPRO was able to detect changes in wheat's rigidity caused by tricep or stretched SUAL muscle as a result of an altered ankle angle [31]. In a further examination of the AT and plantar fascia tissue in healthy persons, there was only a small difference in stiffness values when tendons were subjected to dorsiflexion at 0° [32]. Taş *et al*. (2019) measured the Achilles tendon rigidity with the ankle joint at 0° and 10° dorsiflexion and found that the MyotonPRO was extremely reliable [33]. Melissa and al. (2015) found that the MyotonPRO could accurately and objectively assess muscle rigidity in the body's tiniest muscles, including the eminence thenar and perineal muscles. Indeed, the author had demonstrated good intra-evaluator reliability to the extent of muscle rigidity using MyotonPRO [33]. As a result, numerous studies have proven the effectiveness of MyotonPRO to assess muscle stiffness in various muscle groups and situations [34]. This research provided the new evidence that the inter-operator and intra-operator reliability for assessing erector spinal muscles stiffness at different point during healthy people is good to outstanding whether inter operators or intra operators.

In addition, we were consistent with the study of Parwu, Z. and al2020 who have shown that MyotonPRO has a good reliability in measuring biomechanical parameters for lumbar extensor myofascial tension at different operators [35]. The MyotonPRO is a reliable assessment tool for assessing muscle rigidity in different conditions and relaxed positions as well as under loads, with Alessandro Schneebeli and Al.2020 demonstrated that the MyotonPRO was an accurate method of evaluating muscle rigidity when assessed by tensioned tissues or during relaxation [31]. In a study examining the tone and rigidity of femoral quadriceps in healthy volunteers using

MyotonPRO at various angles of the knee, Cheng G and al (2019) have demonstrated that MyotonPro has excellent reliability for measuring their tone and stiffness [36]. By measuring muscle tone and rigidity using MyotonPRO, Wai Leung Lo and Al (2019) were able to demonstrate that these parameters could be replicated [37]. In another study conducted by VIIR and al. (2006), over musculoskeletal disorders in adult women stipulated that the assessment of the tonus, The MyotonPRO device was used to assess the stiffness and flexibility of a relaxed trapeze muscle [38]. Generally, MyotonPRO is an accurate method of quantification of the properties of BioMecanics in individuals with no health problems. These results are comparable with those from earlier studies showing a correlation of muscle stiffness to MyotonPRO's reliability. We found that healthy people showed good to excellent interoperator and intraoperative reliability with regard to the assessment of spine stiffness at 0, 30 and 60 flexion positions in this study.

**Effects of points, positions on stiffness**

The muscle stiffness on L1 was significantly lower than that on L3 and L5 at natural position 0°, 30° and 60° flexion positions in both populations, and patients with chronic LBP performed a lower muscle stiffness on L3 than that on L5 at 30° flexion position on the left side and at all flexion positions on the right side. Although the difference of muscle stiffness between L3 and L5 is not significant in healthy people, the overall tendency in both populations is an increase in order of L1, L3 and L5 at all flexion positions. The possible reason for this finding is that the muscle stiffness might increase as the decrease of the distance to the muscle attachment. Meanwhile, patients with chronic LBP seems to have a wide variation of muscle stiffness of lumbar muscle than healthy people. However, these two vertebrae (L3 vs L5) showed no significant difference at (0°, 30° and 60°) to the right and (at 0° and 30°) on the left ($p>0.05$). This result showed a slight change in natural position and flexion has 30° of the erector spine muscle in healthy people however without any significant on the values of muscle rigidity. This non-significance is justified by the fact that in healthy topics on the left and right the muscles reacted virtually in the same way producing substantially identical stiffness. In another study Bizzinava M *et al*. (2003) had a significant correlation between stiffness and the muscle strength of the quadriceps but also a competing validity between the muscular properties of the forearm and the hand [39]. Additionally, a study on the parameters of the shoulder muscles measured using the MyotonPRO, had shown significant differences in all the parameters [40].

When comparing the muscle stiffness between different positions, 60° flexion increased decreased muscle stiffness on L3 and L5 on both sides in healthy people to the natural position while the position change does not influence the muscle stiffness on L1. This finding might be caused that the L1 point did not deform as much as the other two points when people performing 60° flexion of lumber region. Furthermore, except for a decrease muscle stiffness on left L5 at 60° flexion than that at 30° flexion, there was no significant difference between muscle stiffness at 30° flexion and 60° flexion position on other position in healthy people and patients with chronic LBP. The phenomenon might be explained by that the deformation of muscle from 30° flexion to 60° flexion is not enough for muscle stiffness to significantly decreased. This non-significance can be explained by the fact that muscle rigidity refers to the degree of muscle stiffness when the skeletal muscle is relaxed. Because the most significant and direct factor affecting muscle stiffness is muscle contraction [41]. It is worth to mentioning that the overall tendency is decrease of muscle stiffness at a specific point in order of 0°, 30° and 60° flexion, which might indicate that the muscle stiffness would decrease as the extension of muscle. Our results are identical to those reported by Mitsubiro Masaki *et al*. (2019). In this study the authors had in found that muscle elongation was higher in relation to muscle lumbar erector in the flexion-lateral flexion position [42]. The MyotonPRO has been utilized in research investigations to assess a difference in active contraction of tightening muscle stiffness between male and female subjects, according to (Zinder and Padoue, 2010). At each of the five contraction levels, men generated approximately one-third higher rectus femoris stiffness values than women [43].

In this study, we discovered a statistically significant difference in muscle stiffness between lieft and right side at different region lumbar for bending at different degrees. Comparing the muscular stiffness of the erector spinal (ES) muscles at the ES-L1, ES-L3 and ES-L5 vertebrae in the respective different positions (0°, 30° and 60°) in left and right side, we found that muscle stiffness of the erector spinal muscles in the both side was statiscally identic ($p<0.05$) between L1 vs L3 and L1 vs L5, however, L3 vs L5 were not statistically identic. According to the stiffness or strength of the lumbar muscles. The muscular force is a critical aspect of the human movement that can influence muscle tissue. Indeed, the lumbar spine muscles are tightly coupled with the lumbar muscles via the thoraco-lumbar fascia, allowing the load transfer of the lumbar spine to the lower limbs [44]. In addition, these muscles help control the rotation alignment, while flexing-extension helps maintain pelvic stability [45]. Thus, the contribution of the low lumbar column to the development of low back pain was unknown. A study on the viscoelastic properties of lower lumbar myofascial in patients with ankylosing spondylitis and normal subjects had shown a significantly higher result than the lower lumbar myofascial in patients with ankylosing spondylitis compared to health people ($p<0.001$) [46]. Sadia Ilahia *et al*. (2020) In their study on the quantification of the viscoelastic biomechanical properties of the L3-L4 myofascial at rest of chronic idiopid patients had proved that the myofascial stiffness after a rest period of 10 minutes was larger than initially [15].

In this investigation, there were limitations. Only erector spinae muscle has been assessed in the first place. Secondly, there was no requirement for volunteers to take part in exercise. So, our team's recommendation was that the participants participate in these two tests of 1 and 2 days after a week. This study did not look at the angle of the goniometer. Therefore, the assessment of stiffness modulations in lumbar spine posture is to become a key part of research going forward.

**Conclusion**

This study aimed to evaluate the intra-operator and inter-operator reliability of Erector Spinal muscle stiffness measurements on different test point (L1, L3 and L5) at difference flexion position (0°, 30° and 60°) in healthy people, and to explore the differences of muscle stiffness between healthy people, between muscle stiffness on the different spinal vertebrae (L1, L3 and L5), and between muscle stiffness at different positions (0°, 30° and 60°). The intra-operator and inter-operator reliability of muscle stiffness are good to outstanding regardless of different test points and positions in healthy people. Generally, lumbar muscle stiffness increases in order L1, L3 and L5 in all flexion positions and both populations, while the muscle stiffness decreased in order 0°, 30° and 60° position of all test points.

**Authors contributions**

M.B.C conceived the idea, supervised the research, was the guarantor, and prepared the first draft. B.E.J, MKPR, NF, MSI, LDS, XQW & MF provides research funding and conceived the form and corrected some part of the article. All authors contributed to the article and approved the submitted version.

**References**


1. Hong J, *et al*., Costs associated with treatment of chronic low back pain: an analysis of the UK General Practice Research Database. Spine. 2013;38(1):75-82.
2. Croft PR, *et al*. Outcome of low back pain in general practice: a prospective study. Bmj, 1998;316(7141):1356.
3. Lawrence JP, Greene HS, Grauer JN. Back pain in Athletes. JAAOS-Journal of the American Academy of Orthopaedic Surgeons. 2006;14(13):726-735.
4. Moore A, Mannion J, Moran RW. The efficacy of surface electromyographic biofeedback assisted stretching for the treatment of chronic low back pain: A case-series. Journal of bodywork and movement therapies. 2015;19(1):8-16.
5. Sherman KJ, *et al*. Comparison of yoga versus stretching for chronic low back pain: protocol for the Yoga Exercise Self-care (YES) trial. Trials. 2010;11:36.
6. Bayramoğlu M, *et al*., Isokinetic measurement of trunk muscle strength in women with chronic low-back pain. Am J Phys Med Rehabil. 2001;80(9):650-5.
7. Chaléat-Valayer E, *et al*. Sagittal spino-pelvic alignment in chronic low back pain. Eur Spine J. 2011;20Suppl 5(Suppl 5):634-40.
8. Barrey C, *et al*., Sagittal balance of the pelvis-spine complex and lumbar degenerative diseases. A comparative study about 85 cases. Eur Spine J. 2007;16(9):1459-67.
9. Ergün T, Lakadamyalı H, Sahin MS. The relation between sagittal morphology of the lumbosacral spine and the degree of lumbar intervertebral disc degeneration. Acta Orthop Traumatol Turc. 2010;44(4):293-9.
10. Youdas JW, *et al*. Lumbar lordosis and pelvic inclination in adults with chronic low back pain. Phys Ther. 2000;80(3):261-75.
11. Freeman MD, Woodham MA, Woodham AW. The role of the lumbar multifidus in chronic low back pain: a review. PM&R. 2010;2(2):142-146.
12. Hides JA, *et al*., Effect of stabilization training on multifidus muscle cross-sectional area among young elite cricketers with low back pain. J Orthop Sports Phys Ther. 2008;38(3):101-8.
13. França FR, *et al*., Segmental stabilization and muscular strengthening in chronic low back pain: a comparative study. Clinics. 2010;65:1013-1017.
14. White A, *et al*., Biomechanical properties of low back myofascial tissue in younger adult ankylosing spondylitis patients and matched healthy control subjects. Clin Biomech (Bristol, Avon). 2018;57:67-73.
15. Andonian BJ., *et al*., Greater Resting Lumbar Extensor Myofascial Stiffness in Younger Ankylosing Spondylitis Patients Than Age-Comparable Healthy Volunteers Quantified by Myotonometry. Arch Phys Med Rehabil. 2015;96(11):2041-7.
16. Hu X, *et al*., Quantifying paraspinal muscle tone and stiffness in young adults with chronic low back pain: a reliability study. Sci Rep. 2018;8(1):14343.
17. Nair K, *et al*., Stiffness of resting lumbar myofascia in healthy young subjects quantified using a handheld myotonometer and concurrently with surface electromyography monitoring. Journal of bodywork and movement therapies. 2016;20(2):388-396.
18. Masaki M, *et al*., Association of low back pain with muscle stiffness and muscle mass of the lumbar back muscles, and sagittal spinal alignment in young and middle-aged medical workers. Clin Biomech (Bristol, Avon). 2017;49:128-133.
19. Abbott JH, *et al*., Manual physical assessment of spinal segmental motion: intent and validity. Man Ther. 2009;14(1):36-44.
20. Seffinger MA, *et al*., Reliability of spinal palpation for diagnosis of back and neck pain: a systematic review of the literature. Spine. 2004;29(19):E413-E425.
21. Jonsson A, Rasmussen-Barr E. Intra- and inter-rater reliability of movement and palpation tests in patients with neck pain: A systematic review. Physiother Theory Pract. 2018;34(3):165-180.
22. Dresner MA, *et al*., Magnetic resonance elastography of skeletal muscle. J Magn Reson Imaging. 2001;13(2):269-76.
23. Qiu W, *et al*., A new shear wave imaging system for ultrasound elastography. Annu Int Conf IEEE Eng Med Biol Soc; c2015. p. 3847-50.
24. Huang J, *et al*., Assessment of passive stiffness of medial and lateral heads of gastrocnemius muscle, Achilles tendon, and plantar fascia at different ankle and knee positions using the MyotonPRO. Medical science monitor: International Medical Journal of Experimental and Clinical Research. 2018;24:7570.
25. Liu CL, *et al*., Assessing the viscoelastic properties of upper trapezius muscle: Intra- and inter-tester reliability and the effect of shoulder elevation. J Electromyogr Kinesiol. 2018;43:226-229.
26. Feng Y, *et al*., Assessing the elastic properties of skeletal muscle and tendon using shearwave ultrasound elastography and MyotonPRO. Scientific reports. 2018;8(1):1-9.
27. Aird L, Samuel D, Stokes M. Quadriceps muscle tone, elasticity and stiffness in older males: reliability and symmetry using the MyotonPRO. Archives of gerontology and geriatrics. 2012 Sep 1;55(2):e31-9.
28. Sipaviciene S, Kliziene I, Pozeriene J, Zaicenkoviene K. Effects of a twelve-week program of lumbar-stabilization exercises on multifidus muscles, isokinetic peak torque and pain for women with chronic low back pain. J Pain Relief. 2018;7(309):1-0.
29. Van Deun B, Hobbelen JS, Cagnie B, Van Eetvelde B, Van Den Noortgate N, Cambier D. Reproducible measurements of muscle characteristics using the MyotonPRO device: comparison between individuals with and without paratonia. Journal of geriatric physical therapy. 2018 Oct 1;41(4):194-203.
30. Chuang LL, Wu CY, Lin KC. Reliability, validity, and responsiveness of myotonometric measurement of muscle tone, elasticity, and stiffness in patients with stroke. Archives of physical medicine and rehabilitation. 2012 Mar 1;93(3):532-40.
31. Schneebeli A, Falla D, Clijsen R, Barbero M. Myotonometry for the evaluation of Achilles tendon mechanical properties: a reliability and construct validity study. BMJ open sport & exercise medicine. 2020 Feb 1;6(1):e000726.
32. Orner S, Kratzer W, Schmidberger J, Grüner B. Quantitative tissue parameters of Achilles tendon and plantar fascia in healthy subjects using a handheld myotonometer. Journal of bodywork and movement therapies. 2018 Jan 1;22(1):105-11.

33. Taş S, Salkın Y. An investigation of the sex-related differences in the stiffness of the Achilles tendon and gastrocnemius muscle: Inter-observer reliability and inter-day repeatability and the effect of ankle joint motion. The Foot. 2019 Dec 1;41:44-50.
34. Jeon M, Youn K, Yang S. Reliability and quantification of gastrocnemius elasticity at relaxing and at submaximal contracted condition. Medical ultrasonography. 2018 Aug 30;20(3):342-7.
35. Davidson MJ, Bryant AL, Bower WF, Frawley HC. Myotonometry reliably measures muscle stiffness in the thenar and perineal muscles. Physiotherapy Canada. 2017;69(2):104-12.
36. Chen G, Wu J, Chen G, Lu Y, Ren W, Xu W, *et al.* Reliability of a portable device for quantifying tone and stiffness of quadriceps femoris and patellar tendon at different knee flexion angles. PloS one. 2019 Jul 31;14(7):e0220521.
37. Lo WL, Yu Q, Mao Y, Li W, Hu C, Li L. Lumbar muscles biomechanical characteristics in young people with chronic spinal pain. BMC musculoskeletal disorders. 2019 Dec;20(1):1-9.
38. Viir R, Laiho K, Kramarenko J, Mikkelsson M. Repeatability of trapezius muscle tone assessment by a myometric method. Journal of Mechanics in Medicine and Biology. 2006 Jun;6(02):215-28.
39. Farasyn A, Meeusen R. The influence of non-specific low back pain on pressure pain thresholds and disability. European Journal of Pain. 2005 Aug 1;9(4):375-81.
40. Bizzini M, Mannion AF. Reliability of a new, hand-held device for assessing skeletal muscle stiffness. Clinical Biomechanics. 2003 Jun 1;18(5):459-61.
41. Ilahi S, Masi AT, White A, *et al.* Quantified biomechanical properties of lower lumbar myofascia in younger adults with chronic idiopathic low back pain and matched healthy controls [J]. Clinical Biomechanics. 2020;73:78-85.
42. Yeo SM, Kang H, AN S, Cheong I, Kim Y, Hwang JH. Mechanical Properties of Muscles around the Shoulder in Breast Cancer Patients: Intra-rater and Inter-rater Reliability of the MyotonPRO. Pm&r. 2020 Apr;12(4):374-81.
43. Zinder SM, Padua DA. Reliability, validity, and precision of a handheld myometer for assessing *in vivo* muscle stiffness. Journal of sport rehabilitation. 2011 Aug 1;20(3):2010_0051.
44. Mueller MJAKSM. Tissue adaptation to physical stress: a proposed "Physical Stress Theory" to guide physical therapist practice, education, and research [J]. Physical therapy. 2002;82(4):383-403.
45. Youdas JW, Garrett TR, Egan KS, *et al*., Lumbar lordosis and pelvic inclination in adults with chronic low back pain [J]. Physical therapy. 2000;80(3):261-275.
46. Masaki M, Ji X, Yamauchi T, *et al*., Effects of the trunk position on muscle stiffness that reflects elongation of the lumbar erector spinae and multifidus muscles: an ultrasonic shear wave elastography study [J]. European Journal of Applied Physiology. 2019;119(5):1085-1091.

**All Author's Names**

**Mboutou Burton Calvin**
1. Department of Sport Rehabilitation, Shanghai University of Sport, Shanghai, P.R China
2. Rehabilitation Therapy Center, Orthopedic Hospital of Shanghai, P.R China

**Bouhika Eddie Janvier**
1. Unité de Recherche de Nutrition, Santé et Motricité Humaine, Institut Supérieur d'Education Physique et Sportive. Université Marien NGOUABI, Brazzaville, BP: 69, République du Congo
2. Laboratory of Education, Health, Expertise and Optimization of Human Performance, High Institute of Physical and Sports Education (ISEPS), Marien Ngouabi University; Po Box 69, Brazzaville, Republic of Congo

**Mabounda Kounga Paul Roger**
1. Laboratory of Education, Health, Expertise and Optimization of Human Performance, High Institute of Physical and Sports Education (ISEPS), Marien Ngouabi University; Po Box 69, Brazzaville, Republic of Congo
2. Laboratoire de biologie Moléculaire, Université du Sport de Shanghai, China

**Nsompi Florent**
1. Laboratory of Education, Health, Expertise and Optimization of Human Performance, High Institute of Physical and Sports Education (ISEPS), Marien Ngouabi University; Po Box 69, Brazzaville, Republic of Congo
2. Unité de Recherche Sport, Santé et Evaluation (UR/SSE). Institut National de la Jeunesse, de l'Education Physique et du Sport (INJEPS), Université d'Abomey-Calavi (UAC). 01 BP: 169. Porto-Novo, Bénin

**Moussouami Innocent Simplice**
1. Laboratory of Education, Health, Expertise and Optimization of Human Performance, High Institute of Physical and Sports Education (ISEPS), Marien Ngouabi University; Po Box 69, Brazzaville, Republic of Congo
2. Unité de Recherche Sport, Santé et Evaluation (UR/SSE). Institut National de la Jeunesse, de l'Education Physique et du Sport (INJEPS), Université d'Abomey-Calavi (UAC). 01 BP: 169. Porto-Novo, Bénin

**Lolo Denove Styven**
1. Unité de Recherche de Nutrition, Santé et Motricité Humaine, Institut Supérieur d'Education Physique et Sportive. Université Marien NGOUABI, Brazzaville, BP: 69, République du Congo
2. Laboratory of Education, Health, Expertise and Optimization of Human Performance, High Institute of Physical and Sports Education (ISEPS), Marien Ngouabi University; Po Box 69, Brazzaville, Republic of Congo

**Xue-Qiang Wang**
1. Department of Sport Rehabilitation, Shanghai University of Sport, Shanghai, P.R China
2. Rehabilitation Therapy Center, Orthopedic Hospital of Shanghai, P.R China

**Mbemba François**
1. Unité de Recherche de Nutrition, Santé et Motricité Humaine, Institut Supérieur d'Education Physique et Sportive. Université Marien NGOUABI, Brazzaville, BP: 69, République du Congo
2. Laboratory of Education, Health, Expertise and Optimization of Human Performance, High Institute of Physical and Sports Education (ISEPS), Marien Ngouabi University; Po Box 69, Brazzaville, Republic of Congo