Eur Spine J (1997) 6:54–62

ORIGINAL ARTICLE

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Reliability of lumbar dynamometry measurements in patients with chronic low back pain with test-retest measurements on different days

Received: 29 December 1995
Revised: 22 March 1996
Accepted: 29 March 1996

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Abstract Lumbar dynamometry is a potentially useful method for assessing the state of trunk muscles in low back pain (LBP) patients. The purpose of this study was to assess the reliability of lumbar dynamometry measurements in chronic LBP patients by conducting test-retest measurements on different days. Thirty-one men and 14 women with chronic LBP participated in this study. The experiments consisted of three sets of lumbar dynamometry measurements (Isostation B200) carried out on three different days with a 2- to 3-day interval. A standard protocol was administered to all subjects, consisting of a range-of-motion measurement about each axis, a 5 s maximum isometric trial about each axis and five dynamic repetitions about each axis against a resistance set at 25% and at 50% of the maximum isometric torque. Correlation coefficients and regression analysis were used to detect possible learning effects. One-way anova and regression analysis were used to assess the reliability of the measurements. High coefficients were found for the correlation between the first and second lumbar dynamometry measurements. Regression analysis showed that the differences between those measurements were not significant. This means that there was no learning effect operating between the first and second lumbar dynamometry measurements. One-way anova showed a reliability higher than 0.90 for the torque and velocity parameters. Reliability for the range-of-motion parameters was somewhat lower: between 0.76 and 0.94. Regression analysis showed no significant differences between the second and third measurements for the torque and velocity parameters. For range-of-motion parameters significant differences were found. From this study it can be concluded that the Isostation B200 provides reliable measures of torque and velocity parameters, but measures of the range-of-motion parameters are unreliable. No learning effect operates between the first and second lumbar dynamometry measurements, which means that a single measurement, with prior warming up and practice, is sufficient to assess the performance of the LBP patient.

Key words Chronic low back pain · Isostation · Reliability · Learning effect

Introduction

Chronic low back pain (LBP) is a major social and economic problem. Globally, 80% of people experience an episode of LBP during their lives. Although most of these complaints resolve themselves within a couple of weeks, about 10% become chronic or recurrent [9]. In the Netherlands 1.4 million guilders every hour are spent on LBP [8]. The high costs are related not only to medical and surgical care, but also to lost work time [7], long-term disability [15], insurance and social security payments [8].

The spine comprises many small well-camouflaged joints and deep muscles with complex multiplanor movements and interconnections. This complexity makes the assessment of LBP difficult, and leaves the physician nearly totally reliant on subjective pain complaints, radiographic imaging and clinical examination. These findings are often insufficient to get an objective image of the state of health of LBP patients and do not explain their complaints. Besides this, therapies are often not successful, which results in unnecessary and prolonged physiotherapy, surgery and use of medicines. From this it can be concluded that there is an urgent need for a method for functional assessment of the LBP patient.

A potentially promising method is lumbar dynamometry. Many LBP patients develop a "deconditioning syndrome" [9]. Patients develop pain and illness behaviour, which leads to a deconditioning of the back muscles. This deconditioning in turn reinforces pain and illness behaviour. Patients get caught up in a vicious circle with an ever deteriorating condition of the back muscles. A method for assessing this condition is lumbar dynamometry [6, 9].

To be useful for clinical decision making lumbar dynamometry measurements must be reliable. The reliability of lumbar dynamometry measurements in healthy persons with test-retest measurements within a single experiment and with test-retest measurements on different days has been the subject of previous studies, e.g. Dillard et al. and Parnianpour et al. [3, 12]. Reliability in LBP patients has been presented in only one study [16]. In that study, test-retest measurements were performed within a single experiment. The reliability of lumbar dynamometry measurements for LBP patients with test-retest measurements between experiments on different moments has not been presented and will be investigated in the present study. Some reports have emphasized a learning effect between the first and second lumbar dynamometry measurements [10] and the need to use a second measurement on a separate day as the baseline, to allow for the initial learning effect [1, 2, 11, 13, 14]. In contrast, Szpalski and Hayez [15] and Szpalski et al. [16] found no learning effect between the first and second measurements. The second purpose of this study was, therefore, to determine the possible existence of a learning effect between the first and second lumbar dynamometry measurements.

Materials and methods

Subjects

Forty-five chronic LBP patients (31 men and 14 women) on a waiting-list for treatment at Roessingh Rehabilitation Centre participated in this study. Mean age was 40 (SD = 9) years, mean weight was 81.4 (SD = 13.9) kg and mean height was 177 (SD = 9) cm.

Chronic LBP is defined as orthopaedic or neurological LBP with a minimum duration of 6 months. Patients were selected taking into account the following contraindications:

1. Acute hernia
2. Structural deviations of the spine, such as infections, inflammatory disease, tumour, spinal fracture or deformity, such as spondylolisthesis or scoliosis
3. A history of back surgery in the previous 6 months

Patients were also excluded from the study if they had a medical contraindication for physical training; such as a respiratory disorder, myocardial disorder, hypertension, pregnancy, a history of eye or trunk surgery in the previous 6 months, convulsion or claustrophobia.

All subjects signed a written informed consent prior to participation.

Measurement device

The Isostation B200 (Isotechnologies, Hillsborough, N.C.) (Fig. 1) was used for data collection. The B200 is a triaxial dynamometer that measures angular position, angular velocity and torque about the three primary movement axes of the low back (sagittal, coronal and transverse). The machine is interfaced to a personal computer via an analogue-to-digital converter board that samples nine channels of signals from the B200, at a rate of 50 Hz per channel. The

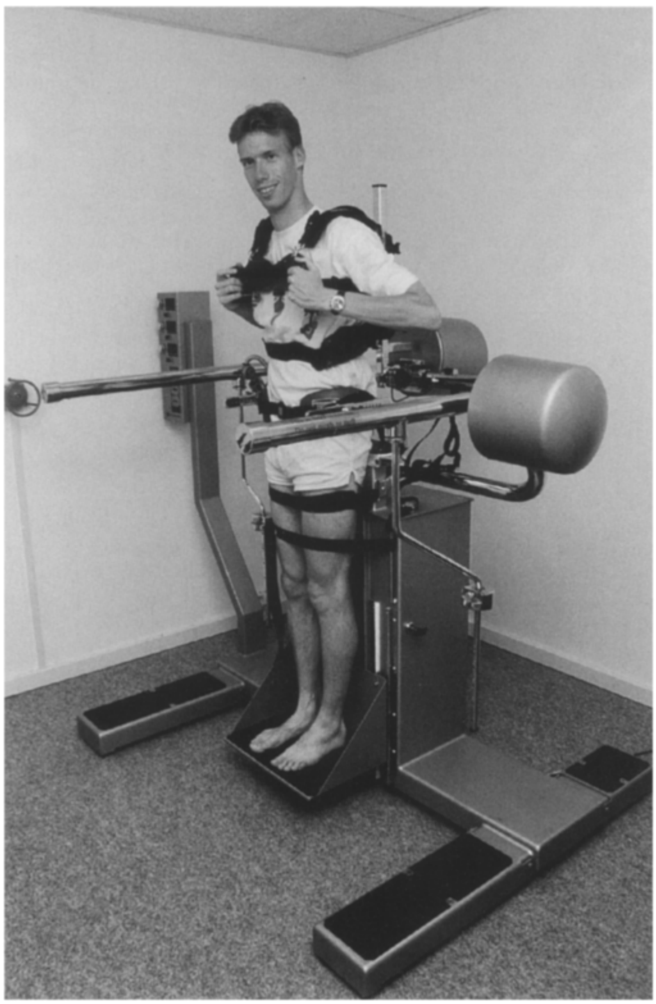

Fig. 1 Patient positioned in the Isostation B200

computer is used to control the resistance provided independently about each axis. Electronically regulated hydraulic pumps associated with each axis provide the resistance. The B200 has a self-calibration sequence built into its software, and this procedure was carried out at the beginning of each test day.

Experiment

To determine reliability at least two measurements are required. In this study the first measurement was performed to overcome a potential learning effect, familiarize the subject with the equipment, decrease anxiety associated with the test situation and give the subject an idea about the degree of effort that is required. Thus, to determine reliability and to determine the possible existence of a learning effect, three lumbar dynamometry measurements were carried out.

Muscle symptoms after unaccustomed strenuous exercise generally settle within 24–48 h, while any physical training effect on muscles is likely to take at least 3 weeks. Therefore, it was decided to carry out the measurements at 2- to 3-day intervals.

Before each lumbar dynamometry measurement was made, a warming up exercise was carried out by the patient. The warming up was performed on a bicycle for 5 min.

The subject was then positioned in a standing posture in the B200, with the lumbosacral junction aligned with the flexion/extension axis of the machine. The subject was firmly restrained using the straps and pads provided, according to the instructions drawn up the manufacturer [4]. The subject was allowed to practise the movements to get an idea of what was required during the experiments.

During the measurements, the following standard (OOC) protocol was administered to all subjects [5]:

- Measurements of unresisted range of motion in each of the six movement directions. Subjects were instructed to move in a slow controlled manner to reach their maximum range of motion.
- Maximum isometric strength measurements in each of the six movement directions.
- Dynamic measurements. Each subject was asked to move as fast as possible five times in each plane against a resistance set at 25% then 50% of the maximum isometric torque generated during the respective isometric tests.

Data analysis

The data obtained were converted to an ASCII format and analysed using SPSS for Windows. The selected parameters used for data analysis in each of the six movement directions were:

- Unresisted range of motion (ROM)
- Maximum isometric strength (MVC)
- ROM, maximum and mean torque (MXT, MNT) and maximum and mean velocity (MXV, MNV), all measured during the dynamic test against a resistance of 25% MVC in each plane
- ROM, MXT, MNT, MXV and MNV, all measured during the dynamic test against a resistance of 50% MVC in each plane

Learning effect

To determine the possible existence of a learning effect, the first and second lumbar dynamometry measurements were used. Pearson correlation coefficients were computed to determine whether a linear relationship existed between the two measurements. Regression analysis was performed to determine significant differences. The regression coefficient, intercept and the 95% confidence interval for both were determined during this analysis. Where no significant difference exists, “1” lies within the 95% confidence interval of the regression coefficient and “0” within the 95% confidence interval of the intercept.

Reliability

Reliability was investigated using the second and third lumbar dynamometry measurements. Reliability was calculated by one-way anova according the following formula:

$$\text{Reliability} = \frac{(F-1)}{(F+H-1)}$$

where H is the number of measurements for each person ($H = 2$ in the present study) and F is the ratio

$$\frac{\text{Between groups mean square}}{\text{Within groups mean square}}$$

where *between groups mean square* represents the variance between subjects, and *within groups mean square* represents the variance between measurements of the same subject (and is equal to the variance due to measurement error).

This reliability is the same as the intra-class correlation coefficient. Reliability is dependent on the variance between individuals in the population. Greater variability between individuals is associated with higher reliability. So an absolute interpretation of reliability or intra-class correlation coefficient is dangerous, and it is preferable to present the variance among individuals and variance among serial measurements of the same individual separately.

To determine significant differences between the second and third lumbar dynamometry measurements regression analysis was performed. Again, the regression coefficient, intercept, and the 95% confidence interval for both were determined during this analysis.

Results

Learning effect

To investigate whether a learning effect is present, the coefficients of correlation between the first and second lumbar dynamometry measurements were computed. All correlation coefficients were higher than 0.80 with the exception of some range-of-motion parameters. Correlation coefficients for the velocity and torque parameters were higher than 0.90.

Besides computing correlation coefficients, regression analysis was carried out to determine whether the first and second lumbar dynamometry measurements were similar. The results are presented in Table 1.

From this Table it becomes obvious that for almost all parameters (60/72), values of the second lumbar dynamometry measurement are equal to those of the first measurement. For these parameters, “0” lies within the 95% confidence interval of the intercept and “1” within the 95% confidence interval of the regression coefficient.

The exceptions to this were:

- Unresisted ROM in right rotation, MXT and MNT against 50% MVC in right rotation, ROM against 25% MVC in flexion and MNT against 25% MVC in flex-

Table 1 Regression analysis comparing the results of the first and second lumbar dynamometry measurements in 45 patients for a range of parameters with varying restistance on the axis. Presented are the intercept, with the regression coefficient given below. The 95% confidence limits are given in parentheses. (*ROM* range of motion, *MVC* maximum isometric strength, *MXT* maximum torque, *MNT* mean torque, *MXV* maximum velocity, *MNV* mean velocity)

Parameters	Resistance (%MVC)	Flexion	Extension	Left lateral flexion	Right lateral flexion	Left rotation	Right rotation
ROM	0	2.80 (–3.25– 8.85)	–0.23 (–4.27–3.81)	–1.98 (–7.12– 3.17)	2.08 (–2.42– 6.57)	–4.38 (–9.98 – 1.22)	6.12 (0.53–11.71)
		0.89 (0.75– 1.04)	0.89 (0.71–1.07)	0.89 (0.70– 1.08)	0.89 (0.73– 1.05)	0.96 (0.72 – 1.19)	0.84 (0.62– 1.06)
	25	5.77 (1.28–10.25)	–1.50 (–5.34–2.34)	0.57 (–5.26– 4.40)	–0.18 (–3.73– 3.38)	–4.44 (–12.17 – 3.29)	5.18 (–2.00–12.37)
		0.96 (0.85– 1.08)	0.90 (0.72–1.08)	1.05 (0.90– 1.19)	1.01 (0.88– 1.14)	0.85 (0.56 – 1.14)	0.79 (0.53– 1.04)
	50	3.21 (–0.25– 6.68)	–1.52 (–5.69–2.66)	0.15 (–4.27– 4.57)	–0.73 (–4.78– 3.32)	–2.39 (–7.77 – 3.00)	3.89 (–0.66– 8.44)
		0.97 (0.88– 1.05)	0.79 (0.59–0.98)	1.02 (0.84– 1.20)	0.98 (0.84– 1.13)	0.88 (0.65 – 1.11)	0.83 (0.65– 1.01)
MVC		12.0 (–1.9 –25.9)	–7.99 (–21.6–5.58)	–11.65 (–25.04– 1.75)	6.14 (–4.99–17.27)	–1.10 (–9.09 – 6.89)	12.16 (3.02–21.30)
		0.97 (0.86– 1.09)	1.00 (0.91–1.10)	0.95 (0.85– 1.06)	0.99 (0.91– 1.08)	1.11 (0.98 – 1.23)	0.90 (0.77– 1.04)
MXT	25	4.16 (–0.78– 9.10)	0.18 (–3.56–3.92)	–5.82 (–10.41––1.23)	–0.61 (–4.98– 3.76)	–1.76 (–4.61 – 1.08)	2.08 (–0.72– 4.88)
		0.96 (0.85– 1.08)	1.08 (0.98–1.17)	0.90 (0.79– 1.01)	1.01 (0.90– 1.12)	1.04 (0.91 – 1.18)	1.00 (0.86– 1.14)
	50	6.28 (–1.21–13.8)	–1.02 (–7.16–5.13)	–6.80 (–13.64– 0.46)	1.59 (–5.24– 8.42)	–5.67 (–11.05 ––0.30)	5.30 (0.39–10.20)
		0.95 (0.85– 1.06)	1.05 (0.96–1.13)	0.92 (0.82– 1.02)	0.97 (0.87– 1.07)	0.97 (0.84 – 1.10)	0.96 (0.84– 1.09)
MNT	25	5.33 (1.27– 9.39)	–0.54 (–3.47–2.38)	–4.29 (–7.78––0.80)	–0.47 (–3.66– 2.71)	–1.44 (–3.85 – 0.96)	1.75 (–0.52– 1.12)
		0.90 (0.77– 1.03)	1.08 (0.99–1.18)	0.92 (0.82– 1.02)	1.02 (0.92– 1.13)	1.05 (0.91 – 1.18)	0.99 (0.86– 1.13)
	50	5.93 (–0.33–12.20)	–1.26 (–6.46–3.93)	–4.06 (–9.07– 0.96)	–0.22 (–4.98– 4.55)	–3.14 (–6.86 – 0.58)	3.59 (0.07– 7.10)
		0.95 (0.84– 1.06)	1.04 (0.95–1.13)	0.95 (0.86– 1.04)	1.01 (0.92– 1.10)	1.00 (0.92 – 1.15)	1.00 (0.89– 1.12)
MXV	25	6.65 (–2.79–16.10)	–3.25 (–13.19–6.69)	2.97 (–7.93–13.86)	–1.38 (–12.42– 9.67)	–0.66 (–10.08 – 8.76)	–0.67 (–9.76– 8.42)
		1.00 (0.90– 1.11)	1.09 (0.97–1.21)	1.12 (0.99– 1.25)	1.09 (0.96– 1.23)	1.11 (0.98 – 1.24)	1.13 (1.01– 1.26)
	50	2.88 (–5.92–11.68)	–0.32 (–8.32–7.69)	1.77 (–6.27– 9.81)	–2.21 (–10.65– 6.23)	–7.97 (–16.88 – 0.94)	5.15 (–3.70–14.00)
		0.96 (0.86– 1.07)	1.05 (0.95–1.14)	1.03 (0.93– 1.12)	1.02 (0.91– 1.12)	0.90 (0.77 – 1.03)	0.94 (0.81– 1.07)
MNV	25	3.31 (–1.84– 8.45)	–0.75 (–6.12–4.65)	–0.08 (–6.63– 6.47)	1.00 (–3.97– 5.97)	–0.56 (–5.73 – 4.60)	1.91 (–3.77– 7.59)
		1.09 (0.96– 1.22)	1.19 (1.07–1.32)	1.10 (0.95– 1.24)	1.07 (0.95– 1.19)	1.12 (0.997– 1.23)	1.05 (0.91– 1.19)
	50	3.99 (–1.03– 9.02)	–0.86 (–6.13–4.42)	0.23 (–4.72– 5.19)	–0.37 (–4.66– 3.92)	–4.82 (–9.8 – 0.17)	4.02 (–0.70– 8.74)
		0.96 (0.84– 1.09)	1.08 (0.97–1.20)	1.03 (0.92– 1.14)	1.04 (0.93– 1.14)	0.90 (0.77 – 1.02)	0.88 (0.75– 1.01)

Table 2 Reliability of lumbar dynamometry measurements as determined by one-way anova, for a range of parameters with varying resistance on the axis

Parameter	Resistance (%MVC)	Flexion	Extension	Left. lateral flexion	Right lateral flexion	Left rotation	Right rotation
ROM	0	0.896	0.771	0.870	0.883	0.900	0.847
	25	0.932	0.831	0.914	0.900	0.897	0.800
	50	0.936	0.755	0.914	0.904	0.775	0.807
MVC		0.912	0.918	0.945	0.950	0.907	0.922
MXT	25	0.928	0.934	0.943	0.909	0.932	0.927
	50	0.924	0.929	0.941	0.935	0.940	0.942
MNT	25	0.911	0.932	0.948	0.915	0.934	0.926
	50	0.917	0.930	0.942	0.930	0.944	0.948
MXV	25	0.952	0.953	0.932	0.933	0.936	0.926
	50	0.916	0.913	0.918	0.921	0.940	0.917
MNV	25	0.945	0.948	0.932	0.927	0.909	0.919
	50	0.921	0.928	0.918	0.922	0.937	0.916

ion. For these parameters "0" was situated below the 95% confidence interval of the intercept, which indicates higher values for the second lumbar dynamometry measurement than for the first.

- MXT and MNT against 25% MVC in left lateral flexion and MXT against 50% MVC in left rotation. For these parameters "0" was situated above the 95% confidence interval of the intercept, which indicates higher values for the first lumbar dynamometry measurement.
- ROM against 50% MVC in extension. "1" was situated above the 95% confidence interval of the regression coefficient, which indicates higher values for the first lumbar dynamometry measurement.
- MXV against 25% MVC in right rotation and MNV against 50% MVC in extension. "1" was situated below the 95% confidence interval of the regression coefficient, which indicates higher values for the second lumbar dynamometry measurement.

In all, 8 of the 72 parameters showed higher values for the second lumbar dynamometry measurement than for the first.

Table 3 Variance between subjects (*intersubject variance*) and variance between serial measurements of the same subject (*intrasubject variance*) for the range-of-motion and isometric strength parameters in the different planes of motion with no restistance on the axis

Parameter	Intersubject variance	Intrasubject variance
ROM		
Flexion	205.19	23.77
Extension	62.62	18.60
Left lateral flexion	73.36	10.95
Right lateral flexion	70.62	9.39
Left rotation	81.74	9.12
Right rotation	79.47	14.35
MVC		
Flexion	5066.14	484.45
Extension	6717.27	602.67
Left lateral flexion	4975.79	285.06
Right lateral flexion	4725.3	249.08
Left rotation	1489.12	152.8
Right rotation	1223.08	103.07

Reliability

To determine the reliability of lumbar dynamometry, the second and third measurements were used. The values for reliability, determined by one-way anova, are presented in Table 2.

This table shows that in all cases except for some range-of-motion parameters reliability is higher than 0.80. For the torque and velocity parameters reliability is higher than 0.90. Reliability is dependent on the variance between individuals in the population. Reliability is higher in a heterogeneous population than in a homogeneous population. An absolute interpretation of the reliability is therefore dangerous. For this reason interindividual variance and intraindividual variance are presented separately (Tables 3, 4).

These results provide information about the linear relationship between the second and third lumbar dynamometry measurements but show nothing about the differences between the measurements. To determine significant differences between the measurements, regression analysis was performed, the results of which are presented in Table 5. This table shows that for 55 of the 72 parameters no significant differences were found between the third and second lumbar dynamometry measurements. For those parameters the regression coefficient was not significantly

Table 4 Intersubject and intrasubject variance for the ROM, MXT, MNT, MXV, and MNV parameters measured during the dynamic measurements with varying resistance on the axis

Parameter	Resistance (% MVC)	Interindividual variance	Intraindividual variance	Resistance (% MVC)	Interindividual variance	Intraindividual variance
ROM						
Flexion	25	244.5	17.90	50	268.96	18.23
Extension		60.5	12.35		50.93	16.54
Left lateral flexion		97.22	9.14		94.39	8.83
Right lateral flexion		97.84	11.03		94.67	10.08
Left rotation		95.06	10.90		70.64	20.56
Right rotation		75.30	20.05		73.98	10.69
MXT						
Flexion	25	512.65	39.50	50	1601.91	131.56
Extension		571.19	40.28		1770.77	135.77
Left lateral flexion		378.18	22.89		877.18	54.58
Right lateral flexion		366.20	36.57		861.92	59.62
Left rotation		139.99	10.15		527.44	33.56
Right rotation		141.59	11.12		510.40	31.20
MNT						
Flexion	25	275.60	26.95	50	1055.92	96.00
Extension		399.06	28.91		1285.37	97.20
Left lateral flexion		274.34	14.90		588.75	36.30
Right lateral flexion		251.11	23.41		556.96	41.65
Left rotation		104.85	7.36		389.22	23.02
Right rotation		99.50	7.94		355.83	19.61
MXV						
Flexion	25	3045.34	154.98	50	2134.38	196.77
Extension		2924.06	144.28		2690.53	256.01
Left lateral flexion		2662.35	195.10		2211.90	198.49
Right lateral flexion		2700.16	193.56		2322.90	199.00
Left rotation		2120.15	144.61		1413.66	89.48
Right rotation		2150.86	172.47		1524.18	38.66
MNV						
Flexion	25	824.74	47.91	50	631.77	53.99
Extension		1181.98	64.55		949.75	73.19
Left lateral flexion		901.41	65.42		783.56	69.61
Right lateral flexion		785.08	62.08		731.32	61.66
Left rotation		849.04	84.63		573.54	38.58
Right rotation		743.40	65.38		499.05	45.53

different from "1" and the intercept was not significantly different from "0". Differences between the third and second lumbar dynamometry measurements were found for 12 of the 18 ROM parameters. In half of these cases "0" was situated below the 95% confidence interval of the intercept and in the other half, above the 95% confidence interval. In all these cases "1" was situated above the 95% confidence interval of the regression coefficient.

Significant differences were also found for MXT and MNT in right rotation against a resistance of 25% MVC. "0" was situated below the 95% confidence interval of the intercept. For MXV and MNV in flexion against a resistance of 50% MVC, "0" was situated below the 95% confidence interval of the intercept and "1" was situated above the 95% confidence interval of the regression coefficient. For MNV against 50% MVC in extension, "0" was situated above the 95% confidence interval of the intercept.

In summary, there were no significant differences between the second and third lumbar dynamometry measurements for almost all torque and velocity parameters. This was in contrast with the range-of-motion measurements, for which a significant difference was found in 12 of the 18 parameters.

Table 5 Regression analysis comparing the results of the second and third lumbar dynamometry measurements in 45 patients for a range of parameters with varying restistance on the axis. Presented are the intercept, with the regression coefficient given below. The 95% confidence limits are given in parentheses

Parameters	Resistance (%MVC)	Flexion	Extension	Left lateral flexion	Right lateral flexion	Left rotation	Right rotation
ROM	0	5.84 (0.78–10.90)	–3.90 (–8.10– 0.31)	–4.72 (–8.54––0.90)	4.16 (0.30– 8.02)	–3.46 (–7.55– 6.23)	4.39 (–0.72– 9.51)
		0.87 (0.74– 0.99)	0.83 (0.62– 1.03)	0.84 (0.69– 0.98)	0.88 (0.73– 1.02)	0.88 (0.72– 1.03)	0.91 (0.72– 1.11)
	25	3.78 (–0.63– 8.19)	–1.64 (–5.37– 2.08)	–3.87 (–7.05––0.68)	4.36 (0.85– 7.87)	–4.90 (–9.30––0.50)	2.20 (–5.62–10.02)
		0.89 (0.79– 0.996)	0.94 (0.76– 1.12)	0.87 (0.75– 0.98)	0.86 (0.73– 0.99)	0.81 (0.65– 0.97)	0.97 (0.67– 1.25)
	50	4.17 (0.16– 8.19)	–4.36 (–7.93––0.78)	–3.88 (–6.75––1.01)	4.81 (1.77– 7.84)	–6.92 (–11.2 ––2.62)	4.61 (–0.72– 9.94)
		0.87 (0.78– 0.97)	0.87 (0.68– 1.06)	0.84 (0.72– 0.95)	0.81 (0.70– 0.93)	0.63 (0.45– 0.82)	0.82 (0.59– 1.04)
MVC		9.67 (–6.51–25.84)	–8.9 (–26.33– 8.52)	–4.55 (–18.13– 9.04)	8.43 (–4.56–21.42)	–6.95 (–16.08– 2.17)	6.61 (–1.98–15.21)
		0.92 (0.79– 1.04)	0.94 (0.83– 1.06)	1.02 (0.91– 1.12)	0.96 (0.86– 1.06)	0.88 (0.76– 1.01)	0.91 (0.79– 1.03)
MXT	25	1.82 (–3.33– 6.97)	2.92 (–7.39– 1.55)	–0.47 (–5.02– 4.09)	3.53 (–1.58– 8.64)	–2.07 (–4.63– 0.49)	2.64 (0.12– 5.14)
		1.00 (0.89– 1.12)	0.95 (0.85– 1.05)	1.03 (0.92– 1.13)	0.99 (0.86– 1.12)	0.89 (0.79– 1.00)	0.90 (0.79– 1.02)
	50	4.30 (–4.55–13.15)	–5.69 (–13.52– 2.14)	–4.71 (–12.05– 2.62)	6.74 (–0.34–13.82)	–2.20 (–6.98– 2.58)	2.51 (–1.98– 7.00)
		0.97 (0.85– 1.09)	0.93 (0.82– 1.03)	0.97 (0.86– 1.07)	0.95 (0.84– 1.05)	0.95 (0.84– 1.05)	0.96 (0.86– 1.07)
MNT	25	2.13 (–2.2 – 6.47)	–2.37 (–5.94– 1.21)	–0.78 (–4.28– 2.71)	2.69 (–1.26– 6.64)	–1.68 (–3.81– 0.45)	2.25 (0.17– 4.32)
		0.98 (0.85– 1.11)	0.94 (0.84– 1.05)	1.02 (0.93– 1.12)	0.99 (0.87– 1.12)	0.90 (0.79– 1.00)	0.91 (0.79– 1.02)
	50	3.70 (–3.92–11.3)	–4.94 (–11.3 – 1.46)	–3.11 (–9.08– 2.86)	4.74 (–1.19–10.67)	–1.88 (–5.75– 2.00)	1.92 (–1.59– 5.43)
		0.97 (0.85– 1.10)	0.93 (0.82– 1.03)	0.97 (0.87– 1.08)	0.95 (0.83– 1.06)	0.95 (0.85– 1.06)	0.96 (0.86– 1.06)
MXV	25	7.51 (–1.26–16.27)	–4.88 (–12.6 – 2.82)	–8.39 (–18.77– 1.99)	6.60 (–3.77–16.97)	–4.01 (–13.3 – 5.31)	4.94 (–5.08–14.95)
		0.97 (0.88– 1.06)	1.02 (0.94– 1.10)	0.95 (0.84– 1.06)	0.98 (0.87– 1.09)	1.01 (0.90– 1.12)	1.00 (0.88– 1.12)
	50	10.91 (1.10–20.72)	–10.20 (–20.53– 0.13)	–9.00 (–19.12– 1.07)	8.61 (–1.28–18.50)	–3.72 (–11.21– 3.78)	5.89 (–2.95–14.74)
		0.86 (0.75– 0.97)	0.93 (0.81– 1.04)	0.95 (0.83– 1.07)	0.96 (0.84– 1.08)	0.97 (0.86– 1.08)	0.93 (0.81– 1.06)
MNV	25	4.09 (–0.49– 8.67)	–3.37 (–7.89– 1.14)	–4.47 (–10.10– 1.15)	3.35 (–1.99– 8.70)	–2.26 (–8.86– 4.34)	2.73 (–3.07– 8.53)
		0.98 (0.89– 1.08)	1.05 (0.97– 1.13)	0.96 (0.87– 1.10)	1.01 (0.89– 1.12)	1.05 (0.92– 1.19)	1.02 (0.89– 1.14)
	50	5.47 (0.64–10.31)	–5.84 (–11.08––0.60)	–5.22 (–10.81– 0.37)	4.31 (–0.74– 9.35)	–1.92 (–6.40– 2.57)	2.44 (–2.29– 7.18)
		0.87 (0.76– 0.98)	0.93 (0.83– 1.03)	0.96 (0.84– 1.08)	0.96 (0.84– 1.08)	1.00 (0.89– 1.12)	0.97 (0.84– 1.10)

Discussion

This study was conducted to investigate the possible existence of a learning effect between the first and second lumbar dynamometry measurements carried out with the Isostation B200, and to investigate whether lumbar dynamometry measurements are reliable for LBP patients if test-retest measurements are performed on different days.

Learning effect

Correlation coefficients for the first and second lumbar dynamometry measurements are high for all parameters in all three planes of motion. Although very high, the correlations for range of motion appear somewhat lower than those for the torque and velocity parameters. These high correlation coefficients represent a strong linear relationship between the first and second lumbar dynamometry measurements.

The regression analysis for the second against the first lumbar dynamometry measurements showed that there were no significant differences for almost all parameters (60/72). Eight of the 12 parameters for which significant differences were found showed higher values for the second measurement. For the other four parameters higher values were found for the first measurement. Because there was a good linear relationship between the first and second lumbar dynamometry measurements and only 8 out of 72 parameters showed significantly higher values for the second measurement, it can be concluded that no learning effect was in operation between the first and second lumbar dynamometry measurements. This means that patients adapt well and quickly to the testing procedure, and that practice in the Isostation is sufficient to familiarize the subject with the equipment.

In most studies in which the issue of a learning effect has been discussed, significant differences were found between the first and second measurements, that could be attributed to a learning effect [1, 2, 11, 13, 14]. In contrast, the results of Szpalski et al. [16] and Szpalski and Hayez [15] showed, in accordance with the findings of this study, no learning effect.

Szpalski et al. [16] argued that a pilot study revealed no justification for classifying the first lumbar dynamometry measurement as a "preliminary" or "training" measurement. Szpalski and Hayez [15] found no significant learning effect on four lumbar dynamometry measurements of healthy subjects carried out on four different days [10].

Both Szpalski et al. [16] and Szpalski and Hayez [15] used an isoinertial device like the one in this study (Isostation B200). Of the five studies showing a significant learning effect, only Cooke et al. [1] used an Isostation B200. In the other four studies an isokinetic device was used.

It is possible that isoinertial measurements, which allow velocity changes inherent in the natural movement of the trunk, require less habituation than isokinetic measurements, which make use of constant velocity and are therefore less natural.

Reliability

One-way anova showed a reliability higher than 0.90 for torque and velocity parameters. Reliability for range-of-motion parameters appeared somewhat smaller: between 0.76 and 0.94. Regression analysis showed no significant differences for torque and velocity parameters between the second and third lumbar dynamometry measurements. In all these cases the regression coefficient was not significantly different from "1" and the intercept not significantly different from "0". Significant differences were found between the second and third measurements for 12 of the 18 range-of-motion parameters. From this it can be concluded that lumbar dynamometry measurements with test-retest measurements on different days provide reliable measures of torque and velocity parameters. Measures of range of motion are less reliable.

These results are in accordance with the results of other studies concerning reliability of the Isostation B200. Szpalski and Hayez [15] studied the intertest and intermachine reliability of the B200 in 16 healthy people. Experiments were performed on four different devices and sessions were separated by an interval of 7 days. They found that the Isostation B200 provides reliable measures of torque and angular velocity, though there was some concern about the stability of some of the angular displacement measures.

Szpalski et al. [16] examined the reproducibility of lumbar dynamometry measurements for LBP patients with test-retest measurements within a single experiment. They found high reproducibility for all measures in all planes. Reproducibility of performance was highest for torque measurements and lowest for range of motion.

Parnianpour et al. [12] examined the reliability of lumbar dynamometry in healthy subjects with test-retest measurements on different days. They found that torque and velocity measurements were reliable, in contrast to the range-of-motion parameters, which were unreliable. Unreliable results for range of motion were also found by Dillard et al. [3], who showed that the Isostation B200 was a less reliable method of measuring range of lumbar movement than a simple goniometer.

Conclusions

From this study it can be concluded that no learning effect operates between the first and second measurements in lumbar dynamometry. This means that LBP patients adapt well and quickly to the testing procedure and that practice in the Isostation is sufficient to familiarize the subject with the equipment. It can also be concluded that torque and velocity parameters are reliable when test-retest measurements are carried out on different days. This is in contrast to the range-of-motion parameters, which are unreliable. Measuring range of motion is, however, not the primary function of the Isostation, and there are clearly much simpler and more reliable methods of measuring such parameters [3].

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