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Spine Evaluation Device with Visual Feedback

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***Abstract*—**The posteroanterior manipulation technique is usually include in the procedure of the lumbar spine to evaluate the intervertebral motion according to mechanical resistance. The mechanical device with visual feedback was proposed that allows one to analysis the lumbar segments mobility "*in vivo*" facilitating for the therapist to take its treatment evolution. The measuring system uses load cell and displacement sensor to estimate spine stiffness. In this work, the device was tested by 2 therapists, female, applying posteroanterior force techniques to 5 volunteers, female, with frequency of approximately 1.2-1.8 Hz. A test-retest procedure was used for 2 periods of day. The visual feedback results small variation of forces and cycle time during 6 cycles rhythmic application. The stiffness values showed good agreement between test-retest procedures when used same order of maximum forces.

***Keywords*—**Biomechanics, lumber spine stiffness, intervertebral manipulation device, visual feedback

I. Introduction

THE clinical importance of lumber spine segmental mobility is increasing but usually many of their evaluation, eg, hipermobility or hipomobility, were realized depending on the tactical sensibility of therapists. Furthermore, the viscoelastic behavior of the column contributes to the poor reliability of manual judgments of its mobility, [1]. This is because researchers have not been able previously to quantify the viscosity of the lumbar spine in vivo and assess the contribution of viscosity to the lumber stiffness factor. Numerous spinal manipulative therapy techniques exist that produce different forces, loading vectors, and loading rates, providing therapists technique- specific choices for treatment of particular patient conditions and/or spinal level, [2],[3], which carried out to the manual oscillatory pressure experiments in posteroanterior (PA) direction and confirmed that the reliability of data between examiners was very poor. Indeed the use of simple end range of motion appears questionable, while assessing spinal proprioception is recommended in describing lumber dysfunction and discriminating low back pain patients from pain-free controls, [4]. In the case of continuous and repetitive movements or rhythmic movements, there is a ceaseless inflow of performance information. Furthermore, an accurate temporal association of the motor commands is not necessary guaranteed, [5]. In the research of [6], the extension lumber range of motion was affected depending on a periods of measurements who analysis three periods of day.

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Although there is substantial information of the dynamic response of the mobilization procedure was reported little objective evidence to date, except when an automatic assessed machine be used, SAM-spinal assessments machine. However, using the procedure of SAM is difficult to achieve the maximum range of mobilization. Furthermore the dynamic response of lumber spine showed viscoelastic characteristic and the stiffness was evaluated only in the linear zone of force-displacement curve, [7]. This linearization can restrict or hide some dysfunction of lumber vertebrae.

This work consists in obtaining reliability of lumber mobilization technique using a mechanical device with force and displacement sensors. The approach was followed with visual feedback of own therapist by means of PA force graphic. The maximum PA force was selected previously to explore maximum mobilization of the vertebrae and used as target during rhythmic hand movements.

II. Methods

A. Subjects

The PA stiffness testing was carried out with 2 experienced therapists, female, 5 years of manual therapy and 5 healthy volunteers with daily work in a sitting position, female, age 22.2±5.7 years, mass 59.0±9.4 kg and height 1.65±0.05 m. The 2 exclusion criteria were that the absences of low back pain at least 6 months and the spine without surgery history.

B. Assessment Procedure

The examination by palpation was realized before submitting to the stiffness tests that is to seek the maximum mobilization of the vertebrae. Therapists located the lumber spinous processes in L3 disk of each volunteer and tried to bring the practice exercised by means of touch sensibility. This sensibility was perceived by the hand through the mechanical resistance as showed in Fig. 1.

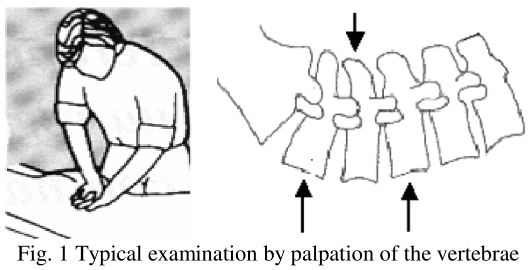


Fig. 1 Typical examination by palpation of the vertebrae

Then, a mobility of L3 disk was evaluate applying a rhythmic PA force, the skin above spinous process while the volunteer lying prone. The maximum force was controlled according to previous examination looking at the monitor screen which showed graphs of displacements and PA forces history.

During the PA force application, the minimum setup force is adjusted in 30N with small helical spring accomplished at load cell and the maximum force for each cycle was controlled by the force´s graphics of monitor screen. The maximum displacement was restricted in 20mm to ensure safety mode. The 6 cycle rhythmic evaluation test on L3 disk with approximately 1 Hz periodic were suggested for therapist. Before the test, the volunteer was instructed to take a deep breath and then hold her breath out during procedure. The test and retest procedure were realized in two periods of day with 3 volunteers and other 2 volunteers were evaluated only 1st period. The 1st period is selected 8-9 hours, morning and 2nd period is 16-17 hours, evening.

C. Mechanical Device

The mechanical device consisted of a plastic rod, 20mm diameter and 80mm length, fixed on load cell, "S" type specially made in our laboratory using 4 strain gage (Kyowa, type KFG, gage factor 2.1, electrical resistance 119.8±0.2 Ω. The static force calibration of load cell showed good repeatability in range of 0-250N, approximately 1.0%. The load cell was fixed on the thin plate, support plate, where therapist´s hands were supported, steel with 100mm width 120mm length and 5mm thickness. The movement of thin plate was guided by the aluminum linear guide (Igus, type WS-10-80) fixed on horizontal arm, rectangular steel tube, 50mm height, 30mm width and 1.5mm thickness. A linear potentiometer (Alpus, 22mm displacement, linearity ±0.5%, resistance 10kΩ) was installed between the support plate and the linear guide. Fig. 2 illustrates the parts of the mechanical device with load cell.

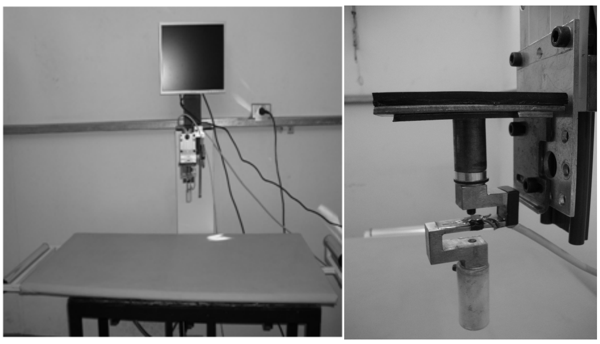


Fig. 2 Illustrate of the mechanical device with force-displacement sensors

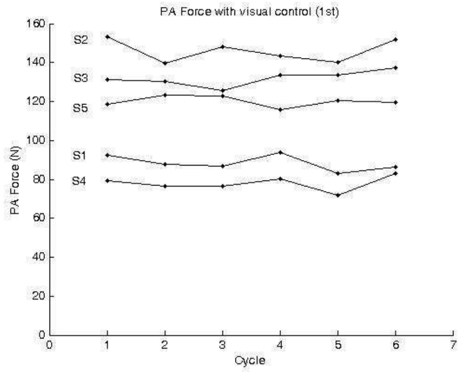
The data of both rod displacement and force were recorded using the signal conditioner (Spider8, HBM) with Catman software of HBM. The signals of force and displacement data were recorded with 100Hz acquisition frequency and followed by a low pass filter, 10Hz. In use, the support plate of device was pressed manually according to described PA application mode.

D. Stiffness calculation

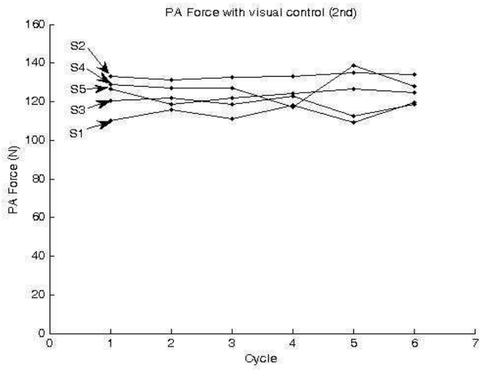
The stiffness was calculated according to the average value of force-displacement curves with 6 cycles measured. However, as the phases of compression and relaxation has different trends and force-displacement plots show the nonlinear characteristic due to viscoelasticity, the values of stiffness were obtained with two modes; PA force 30-80 N, linear range, and 30N-maximum forces, nonlinear range. The calculation procedure was realized using MATLAB software, MathWorks, with EXCEL data sheet.

III. Results

The variation of maximum PA forces during 6 cycles for 1st and 2nd periods is present in Fig. 3 which showed small variation among cycles due to visual feedback. S1 to S5 indicate volunteer 1 to 5 respectively. Although, the results of test-retest showed different magnitude of applied force to same volunteer, principally volunteer S4, but small variation range was observed among inter subject.



(a)



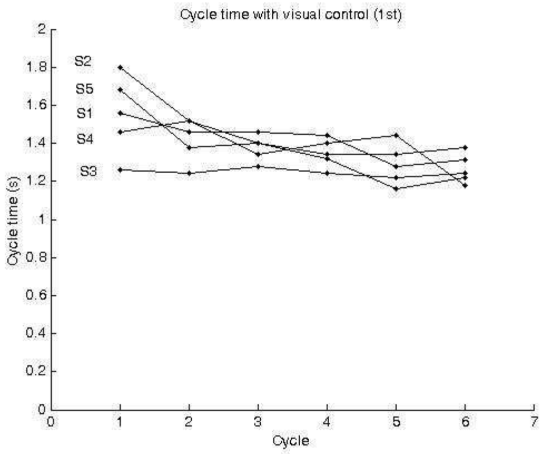
(b)

Fig. 3 Maximum PA force during 6 cycles, a) 1st test, b) 2nd test; therapist 1

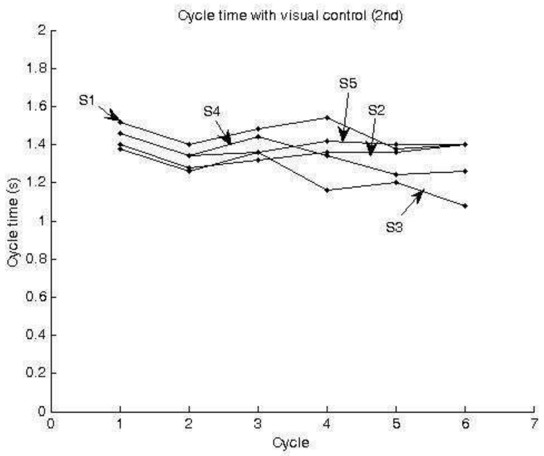
The maximum force applied by therapists for 6 successive cycles are presented in Table I where can be compared 1st and 2nd periods of application. The absence of values for subject 4 and 5 by therapist 2 is the procedure of test and retest are applied only volunteer 1 to 3. The maximum deviation, standard errors, registered in this experience was less than 5.4% which to indicate visual feedback serving not only a low variation of application forces, but for cycle times, Table II.

TABLE I
MAXIMUM PA FORCE APPLIED (N)

	Therap.1	Therap.1	Therap.2	Therap.2
	1st	2nd	1st	2nd
S1	88.4±4.0	113.9±4.3	141.6±3.7	120.6±3.3
S2	146.0±5.9	133.2±1.3	153.9±4.4	101.4±3.5
S3	134.0±3.9	119.1±3.6	129.3±5.5	134.8±3.9
S4	74.2±4.0	128.5±6.9		
S5	118.3±2.8	122.2±3.0		



(a)



(b)

Fig. 4 Cycle time during 6 cycles, a) 1st test, b) 2nd test; therapist 1

The variation of cycle time during 6 cycles for 1st and 2nd periods is present in Fig. 4 that to keep same rhythmic of applied force procedure. In general, the 1st cycle is longer compared with subsequent cycles. The relationship between the maximum PA force variation and the cycle time variation has not detected in our work.

The time variation of each cycle was showed in Table II with 6 successive cycles. The mean cycle time by therapist 2 was longer than therapist 1, however, the standards errors variations were remained same order for two therapists. The test and retest procedure showed small variation of the cycle time between 1st and 2nd trial that indicate correct application of mobilization technique. Furthermore, the significant difference among 5 subjects was recorded. The average rate of compression phase was 0.53±0.03 of cycle time that equivalent in two phases (compression and relaxation).

TABLE II
CYCLE TIME (S)

	Therap.1	Therap.1	Therap.2	Therap.2
	1st	2nd	1st	2nd
S1	1.45±0.10	1.44±0.07	1.67±0.07	1.75±0.15
S2	1.39.0±0.18	1.40±0.04	1.80±0.07	1.86±0.20
S3	1.24±0.02	1.23±0.11	1.45±0.17	1.35±0.11
S4	1.42±0.12	1.34±0.09		
S5	1.35±0.18	1.36±0.05		

The linear stiffness values, average values between compression and relaxation phases, for range of 30N-80N of PA forces were presents in Table III. In this track, it is considered that the stiffness is almost linear for most researchers, [8]. There was a significant difference of linear stiffness values for one of volunteer (S4) with therapist 1 and volunteer 2 (S2) with therapist 2 when compared 1st and 2nd procedures. Author believes that the difference detected between therapists is caused from the selection of maximum forces for each volunteer, associated with poor linearization of force-displacement curves. When the maximum force selected is adequate value which the correspondent PA stiffness is reasonable. These results showed limitation of PA force mobilization procedure that depending on tactile sensibility of each therapist to determine maximum force. In fact, one of the aims of PA force mobilization technique is continuous evaluation of patients where any change of PA stiffness should be detected.

TABLE III
LINEAR STIFFNESS (N/MM)

	Therap.1	Therap.1	Therap.2	Therap.2
	1st	2nd	1st	2nd
S1	22.1(16.4)	20.9(14.6)	20.7(22.5)	21.2(19.6)
S2	27.5(26.2)	31.1(26.4)	30.3(25.1)	12.1(11.9)
S3	27.3(23.4)	30.5(23.0)	40.1(32.1)	41.8(27.3)
S4	19.2(12.8)	24.7(19.8)		
S5	16.9(15.0)	17.5(17.4)		

The values ( ) indicates linear stiffness with PA force 30N – maximum force.

IV. DISCUSSION

In this study, we have quantified how the visual feedback improvement in PA mobilization technique and the test-retest procedure for same subject show reliability of lumber stiffness characteristics. A motor-driven device provides highly reliable evaluation of the lumber stiffness. However, the safeguards and patients protections should be guaranteed and encourage confidence are necessary. The measuring system using in this work is similar with [8] that the human operator perform the test, but computer-interfaced sensors record the force and displacement data. The system differ the mechanical palpation parts and sensor system that guide it vertically to obtained stability during rhythmic force application. The displacement sensor used has a high accuracy (0.01 mm) and linearity (±0.5%). In [8], the longer rod (66 cm length and 2 cm diameter) was used which can be caused instability in procedure.

The maximum PA force was controlled with audible feedback in [8], but in this work visual feedback was adopted with graphic monitor in order to explore maximum mobilization of the target vertebrae. Although, a visual feedback error for only a fraction of cycle can affect subsequent movements, [5]. In fact, a visual identification technique revealed that the motor command was affected not just by the preceding movement, but also by a history of precedent error. In our work, the small variation in PA forces and cycle time were observed and not identified significant error with use of visual feedback. Perhaps, larger cycle time with average time of 1.5 seconds compared with 0.4 seconds used in [5] and only 6 cycles recorded procedure is contributed to insignificant error.

Concerning the cycle time, it is note same order of [8]. The principle difference was regarded the portion of time spent for compression phase and relaxation phase. Whereas [8] used half of the time taken for relaxation phase that differ the commonly PA force procedure, consequently the dynamic response of stiffness characteristics can be changed. The cycle time to compression and relaxation phases was similar in this work that to ensure response of the normal PA force procedure.

Most of research, [3],[4],[8], evaluating PA stiffness in the spine used only the linear zone of the force-displacement curve and to suggest the range of 30-80 N as ideal considering only linear zone of stiffness characteristic. In our work, the maximum force was determined previously with palpation analysis by therapists to explore maximum mobilization of the vertebrae. The minimum force was setup with 30N in all tests. The maximum force recorded was range of 78-154 N. Due to minimum force setup procedure and the previous act of palpation the first cycle data showed no difference stiffness compared with subsequent cycles, then all 6 cycles recorded data were used to stiffness calculation. The maximum force not settled to same magnitude for different volunteer causing significant difference among 5 volunteers and test-retest procedure for same volunteer. Hence, more than 50% of difference in maximum force between test-retest was observed which results significant difference in calculated stiffness value. The results implying that when test-retest procedure be used it is necessary to keep same application force. Moreover, the linear regression fitting of force-displacement curve with nonlinear zone (over 80N) showed same tendency considering with only linear zone. These results showed that nonlinearity of stiffness becomes an important factor in initial phase of compression and final phase of relaxation. However, the nonlinear region may also be important in judgment of abnormal PA stiffness, [9].

V. Conclusion

Visual control helps to apply constant force and maintain the rhythmic movements, however, it is not enough for correct evaluation of lumbar stiffness through the mobilization technique. An accurate forces-temporal association of the motor commands by therapist providing visual feedback in PA force procedure should be used with wariness.

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