Alteration of ligament stiffness can change the spine muscle coordination in flexed positions

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INTRODUCTION

- Ligaments help muscles in stabilizing the spine within physiological ranges of motion by limiting the displacements [1].
- In some cases, the property of ligament can be altered or deteriorated due to spinal disorders and diseases [2].
- The different stiffness of ligaments in stabilizing the spine considering the whole spinal musculature has not been investigated yet.

OBJECTIVE

- To investigate the effect of different ligament stiffness on stabilization of the lumbar spine with comparing the joint resultant forces and muscle forces in various flexed positions.

MATERIALS & METHODS

- The extended spine model to a reference musculoskeletal model using the AnyBody Modeling System v. 4.2 (AnyBody Technology, Aalborg, Denmark) was used in this study [3,4].
- Lumbar ligaments (supraspinous, interspinous, anterior and posterior longitudinal, intertransverse, flavum, and capsular) were added to the base spine model.
- Five ligament stiffness sets were determined from literature (Table). The maximum tensile force set was limited to be 80% of the failure strength [1]
- The three following activities, which assumedly lead to high loads in most ligaments were chosen: standing in a flexed forward; full flexion; and lifting 20 kg during full flexion and joint resultant forces and muscle forces in the spine were predicted for result comparison.

DISCUSSION

- Lumbar stabilization was noticeably affected by the given ligament stiffness.
- Even though no considerable difference was predicted in normalized joint resultant forces depending on the given ligament stiffness (maximum difference, 12%), the trend of the sum of the muscle forces was decreased with increasing ligament stiffness for all three loading cases.
- Also, individual muscle forces and their patterns were considerably affected by ligament stiffness with increasing trend of superficial muscles and decreasing trend of inner short muscles (Table).
- The results of this study showed that besides long and superficial muscles, ligaments also played an important role in stabilizing the spine in flexed positions

REFERENCES

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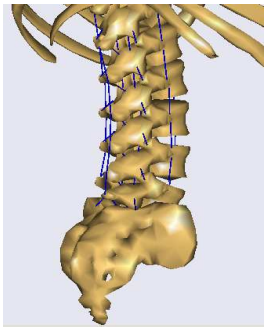
Lumbar spine model with implemented lumbar ligaments



Five sets of ligament tensile forces in N at maximum strains

	SSL	ISL	PLL	ALL	ITL	LF	CL
Minimum	100	50	40	210	70	90	120
Min-Med	150	85	130	280	70	145	190
Median	200	120	220	360	70	200	260
Med-Max	280	140	290	380	70	235	380
Maximum	360	160	360	400	70	270	500

* SSL = supraspinous ligament, ISL = interspinous ligament, ALL,PLL = anterior, posterior longitudinal ligament, LF = ligamentum flavum, CL = capsular ligament

RESULTS

Predicted muscle forces in N for flexed positions

Positions	Ligament Stiffness	Ic	Lg	LM	Ints	Intt	Rt
Flexed Forward	**No Ligaments**	351	541	65	9	7	7
	Minimum	303	449	120	17	12	10
	Min-Med	285	390	150	21	14	11
	Median	264	334	179	23	16	12
	Med-Max	230	260	215	27	18	13
	Maximum	155	216	254	31	21	13
Full Flexion	**No Ligaments**	809	974	205	14	9	9
	Minimum	749	912	203	19	12	10
	Min-Med	743	841	227	24	15	12
	Median	729	776	253	27	18	13
	Med-Max	692	706	283	30	20	14
	Maximum	651	631	317	35	23	16
Lifting flexed	**No Ligaments**	1248	1446	364	19	12	11
	Minimum	1209	1363	339	21	13	11
	Min-Med	1186	1318	331	23	14	11
	Median	1168	1258	349	28	18	13
	Med-Max	1153	1167	380	35	23	16
	Maximum	1126	1071	418	45	29	20

* Sum of forces in each muscle group was used in this comparison. The abbreviation of muscle names indicates: Ic = Iliocostalis; Lg = Longissimus; LM = Lumbar multifidus; Ints = Interspinales; Intt=Intertransversarii; Rt = Rotatores.

* This research was supported by National Agenda Project (NAP) funded by Korea Research Council of Fundamental Science & Technology (P-09-JC-LU63-C01).