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Lumbar Mobility and Low Back Pain During Adolescence

A Longitudinal Three-Year Follow-up Study in Athletes and Controls

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ABSTRACT

In this 3-year longitudinal study, we studied lumbar mobility and the occurrence of low back pain among 98 adolescents who were free of previous severe low back pain: 33 nonathletes (16 boys, 17 girls), 34 boy athletes (ice hockey and soccer players) and 31 girl athletes (figure skaters and gymnasts). During the followup, low back pain lasting longer than 1 week was reported by 29 athletes (15 boys and 14 girls) and by 6 nonathletes (3 boys and 3 girls). In multivariate analyses, participation in sports and low maximal lumbar flexion at the baseline predicted low back pain during the followup among boys; however, these factors accounted for only 16% of the variability between the groups with and without low back pain. Among girls, decreased range of motion in the lower lumbar segments, low maximal lumbar extension, and high body weight at the baseline were predictive of low back pain during the followup, accounting for 31% of the variability between the groups. The girls in the lowest tertile of maximal lumbar extension at baseline had a relative risk of 3.4 to have future low back pain compared with those in the highest tertile. We conclude that the low individual physiologic maximum of lower segment lumbar extension mobility may cause overloading of the low back among athletes involved in sports with frequent maximal lumbar extension and that it predicts future low back pain.

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Among adults there is wide variation in the normal range of sagittal motion of the lumbar spine. The range of motion (ROM) in this region also declines with age.[6] Reduced spinal flexibility has been found to be associated with current[7,25] and previous low back pain.[7,18,19] Low-grade spinal flexibility does not, however, predict occupational back pain in adults.[2,23] Maximal extension of the lumbar spine is uncommon during occupational loading. It is, however, a common maneuver in various sports and in these sports low back pain is also common.[14,15] The reason low back pain occurs in young athletes is often found in the posterior elements of lumbar spine.[15] In particular, there is observational evidence that suggests a high frequency of spondylolysis is caused by repeated maximal extension in sports such as gymnastics.[11]

We studied male athletes, female athletes, and controls in a longitudinal study covering their adolescent growth spurt. The boy athletes participated in soccer and ice hockey, in which maximal lumbar extension is seldom required, and the girl athletes participated in gymnastics and figure skating, in which maximal lumbar extension is a common maneuver. We hypothesized that a low maximum of extension of the lumbar spine predicts future low back pain among athletes in those sports in which maximal lumbar extension is frequently performed.

MATERIALS AND METHODS

Subjects

The subjects of our study were young athletes and nonathletes.[13,14] At baseline, 116 subjects (age range, 10.3 to 13.3 years) were recruited into the study. Informed written consent was obtained from each subject and from a parent or guardian. At baseline, the athletes had been regularly training at least twice a week for at least 2 years. Training was supervised by coaches in various sports clubs. All the boy athletes (ice hockey and soccer players) were involved in similar, moderately strenuous team training programs. The girl athletes (gymnasts and figure skaters) were a more heterogeneous group, following more individual training programs involving, for example, many different types of jumping techniques. At the beginning of the study, the coaches reported that none of the athletes had been forced to interrupt training because of low back pain during the preceding year. During the 3-year follow-up period the strength training programs in our growing subjects were limited to circuit training without extra weights.

The nonathletes were pupils of the same age attending two elementary schools who participated in recreational sports sporadically at most (less than twice a week). During the 1st follow-up year, two nonathletes started to participate in sports actively, and eight athletes quit training or switched to another sport. These 10 subjects, together with 3 athletes and 3 nonathletes who refused to participate in the 1-year follow-up examination, were excluded from our study. During the 2nd and 3rd follow-up years, two subjects refused to continue in the study, some nonathletes increased their level of physical activity during leisure, and one boy athlete and six girl athletes gave up competitive sports (two because of low back pain and four for other reasons). Subjects whose level of physical activity changed during the 2nd or 3rd follow-up year were included in the final study groups. Each had been exposed to physical exercise corresponding to his or her grouping for at least 3 years before the 2nd follow-up year. None of the subjects who gave up sports or discontinued the study during the 1st follow-up year gave low back pain as the main reason. Thus, the grouping of 98 (65 athletes and 33 nonathletes) adolescents remained the same through the follow-up, and they all participated in the 2- and 3-year follow-up examinations. The final study group included 34 boy athletes (mean age at baseline, 11.9 years; range, 11.3 to 12.3), 31 girl athletes (mean age, 11.7 years; range, 10.3 to 13.3), 16 nonathletic boys (mean age, 11.9 years; range, 11.3 to 12.3), and 17 nonathletic girls (mean age, 11.9 years; range, 11.3 to 12.8).

Questionnaire

At baseline and after the first, second, and third follow-up examinations, the subjects completed a questionnaire at home, most of which was identical on these four occasions. At the baseline and the 1- and 3-year follow-up examinations, a study assistant ensured that the questionnaires had been properly completed when the subjects returned them. At the 2-year followup, an almost identical postal questionnaire was successfully completed by the subjects themselves. The questionnaire included items investigating the subjects' past and present physical activity as well as acute injuries causing low back pain and questions taken from a previously developed questionnaire documenting the occurrence of low back pain.[20] Subjects

TABLE 1
Subject's Athletic Training for Their "Own" Events[a]

Parameter	Boys		Girls	
	Ice hockey (N = 17)	Soccer (N = 17)	Gymnastics (N = 14)	Figure skating (N = 17)
Training years before baseline	4.3 (1.0) 3–6	4.8 (1.6) 2–6	5.8 (1.7) 3–8	3.5 (1.5) 2–7
Year before baseline				
Mean training				
Frequency/wk	3.6 (0.7) 3–5	3.0 (0.7) 2–4	5.5 (1.1) 4–9	3.9 (1.6) 2–7
Minutes/wk	281 (83) 180–480	251 (59) 120–360	426 (176) 140–840	608 (366) 240–1230
First year				
Mean training				
Frequency/wk	3.9 (1.1) 3–7	3.9 (1.1) 3–7	6.2 (1.9) 4–12	4.0 (1.8) 2–6
Minutes/wk	351 (126) 180–600	357 (88) 180–510	584 (187) 300–900	694 (467) 180–1320
Second year				
Mean training				
Frequency/wk	3.7 (0.4) 3–4	4.2 (0.8) 3–5	6.7 (2.5) 0–12	4.2 (2.1) 0–7
Minutes/wk	308 (48) 180–360	357 (72) 240–480	570 (233) 0–975	671 (514) 0–1560
Third year				
Mean training				
Frequency/wk	3.9 (1.2) 2–5	4.0 (1.0) 3–6	6.6 (3.6) 0–12	2.9 (3.7) 0–9
Minutes/wk	345 (98) 180–480	383 (145) 180–600	512 (300) 0–1200	379 (551) 0–1530

[a] Data given as mean (SD) and range.

TABLE 2
Age at Baseline and Anthropometry and Flexibility Measurements at Baseline and at Followup[a]

Measurement	Boys		Girls	
	Nonathletes (N = 16)	Athletes (N = 34)	Nonathletes (N = 17)	Athletes (N = 31)
Age (years)				
Baseline	11.9 (0.3)	11.9 (0.3)	11.9 (0.4)	11.7 (0.8)
	11.3–12.3	11.3–12.3	11.3–12.8	10.3–13.3
Height (cm)				
Baseline	149.4 (7.8)	149.5 (5.3)	153.2 (8.0)	145.9 (7.6)
	137–164	141–162	137–168	130–167
Followup	170.7 (7.3)	170.7 (6.6)	165.2 (7.5)	160.5 (5.5)
	157–181	157–186	155–179	146–171
Weight (kg)				
Baseline	37.1 (5.4)	39.7 (5.1)	42.9 (7.9)	35.6 (5.6)
	30–46	31–48	27–58	27–54
Followup	53.1 (8.3)	59.2 (7.8)	57.5 (7.9)	51.0 (5.9)
	37–65	41–71	36–72	36–65
Body mass index				
Baseline	16.6 (1.9)	17.7 (1.8)	18.2 (2.7)	16.6 (1.1)
	14.0–21.1	15.0–21.8	14.4–23.6	14.6–19.4
Followup	18.1 (1.9)	20.2 (1.7)	21.1 (2.9)	19.7 (1.5)
	15.0–21.1	16.7–23.0	15.2–27.7	16.9–22.6
Maximal lumbar extension (deg)				
Baseline	60 (13)	64 (10)	77 (16)	70 (11)
	41–95	42–82	46–103	47–88
Followup	63 (15)	63 (11)	81 (22)	76 (10)
	42–100	42–89	45–130	52–99
Maximal lumbar flexion (deg)				
Baseline	40 (7)	37 (5)	38 (10)	34 (6)
	27–50	29–50	24–71	20–48
Followup	44 (8)	37 (7)	36 (7)	35 (10)
	24–56	25–53	22–48	13–56
Lumbar standing posture (deg)				
Baseline	32 (9)	35 (7)	36 (10)	30 (6)
	16–48	22–48	18–51	21–45
Followup	35 (10)	38 (7)	35 (9)	35 (7)
	22–63	24–55	20–54	21–52
Maximal ROM (deg)				
Baseline	100 (12)	101 (11)	115 (15)	103 (14)
	84–127	73–124	81–143	79–135
Followup	104 (16)	100 (12)	117 (23)	111 (15)
	65–133	75–127	79–155	85–146
Lumbar upper segment ROM (deg)				
Baseline	60 (15)	59 (8)	72 (18)	67 (13)
	42–92	35–74	39–99	51–103
Followup	58 (13)	55 (12)	65 (16)	60 (14)
	37–76	33–78	37–93	37–112
Lumbar lower segment ROM (deg)				
Baseline	41 (7)	43 (8)	43 (10)	37 (10)
	31–57	29–63	31–71	13–61
Followup	47 (10)	45 (10)	52 (18)	51 (10)
	28–65	27–66	18–100	34–70

[a] Data give as mean (SD) and range.

reporting low back pain interfering with school work or leisure activities for at least a 1-week period were determined to have low back pain. Low back pain experienced by the subjects was defined by timing, duration, and location (demonstrated on a drawing). During the followup, all the subjects with prolonged low back pain problems were examined by the first author.

At the 1- and 3-year examinations Tanner's stages of maturity were assessed according to the method of Morris and Udry.[17] The pubertal staging was further divided into three classes: 1) no pubertal development (all of the Tanner parameters, i.e., pubic hair and genitals or breasts of stage 1), 2) ongoing puberty (one of the parameters exceeding stage 1 and none reaching stage 5), and 3) puberty passed (at least one of the parameters of stage 5). At the end of the 1st follow-up year, one nonathletic boy, one boy athlete, and two girl athletes were classified into the "no pubertal development" group on the basis of pubertal staging. The other subjects (N = 94; 96%) were classified into the "ongoing puberty" group. At the 3-year followup five nonathletic girls, two boy athletes, and one girl athlete were classified into the "puberty passed" group, and the rest (N = 90; 92%) were classified into the "ongoing puberty" group.

TABLE 3
Mean (SD) of the Anthropometric Variables and Lumbar Mobility in Subjects With and Without Low Back Pain by Sex

Measurement	Boys: Low back pain No (N = 33)	Boys: Low back pain Yes (N = 17)	Boys: P-value	Girls: Low back pain No (N = 30)	Girls: Low back pain Yes (N = 18)	Girls: P value
Height (cm)						
Baseline	149.0 (6.4)	150.4 (5.6)	0.27	146.9 (7.9)	151.2 (8.7)	0.087
Followup	170.0 (7.1)	172.1 (5.9)	0.31	161.0 (6.0)	164.1 (7.3)	0.11
Increase	21.0 (3.6)	21.7 (3.5)	0.52	14.1 (4.5)	13.0 (5.0)	0.41
Weight (kg)						
Baseline	38.0 (5.2)	40.4 (5.1)	0.13	37.1 (6.5)	39.9 (8.4)	0.19
Followup	55.4 (8.7)	60.8 (6.7)	0.029	52.3 (7.0)	55.0 (7.6)	0.23
Increase	17.4 (4.5)	20.4 (4.3)	0.025	15.3 (4.1)	15.0 (4.2)	0.85
Body-mass index (kg/m^2)						
Baseline	17.1 (2.0)	17.8 (1.5)	0.21	17.1 (1.8)	17.3 (2.3)	0.64
Followup	19.1 (2.1)	20.5 (1.4)	0.018	20.1 (2.2)	20.4 (2.3)	0.72
Increase	2.0 (1.2)	2.7 (1.3)	0.061	3.1 (1.5)	3.0 (1.4)	0.93
Maximal lumbar extension (deg)						
Baseline	62 (11)	66 (11)	0.20	76 (12)	66 (14)	0.021
Followup	61 (14)	64 (12)	0.46	80 (15)	74 (16)	0.16
Change	0 (13)	−1 (9)	0.87	5 (16)	7 (13)	0.58
Maximal lumbar flexion (deg)						
Baseline	39 (6)	36 (6)	0.058	37 (9)	34 (6)	0.15
Followup	41 (7)	37 (9)	0.10	38 (9)	32 (6)	0.039
Change	2 (5)	1 (7)	0.51	1 (8)	−1 (7)	0.36
Lumbar standing posture (deg)						
Baseline	34 (8)	33 (8)	0.75	32 (8)	33 (9)	0.55
Followup	36 (8)	38 (7)	0.67	35 (8)	36 (8)	0.75
Change	2 (8)	5 (4)	0.14	3 (9)	3 (9)	0.77
Lumbar ROM (deg)						
Baseline	101 (11)	102 (11)	0.78	113 (13)	100 (15)	0.0056
Followup	102 (14)	101 (13)	0.79	118 (17)	106 (18)	0.028
Change	2 (14)	0 (11)	0.65	5 (16)	6 (17)	0.94
Lumbar upper segment ROM (deg)						
Baseline	59 (11)	58 (11)	0.68	70 (14)	67 (16)	0.44
Followup	57 (12)	53 (12)	0.27	64 (16)	59 (12)	0.27
Change	−2 (13)	−5 (8)	0.37	−6 (18)	−8 (13)	0.76
Lumbar lower segment ROM (deg)						
Baseline	41 (8)	44 (7)	0.31	43 (10)	34 (8)	0.0045
Followup	45 (9)	48 (11)	0.38	54 (14)	47 (11)	0.077
Change	4 (14)	5 (11)	0.86	12 (15)	14 (14)	0.68

Measurements

At the beginning of the study and at the 3-year followup, each subject participated in physical measurements including height, weight, and measurement of lumbar sagittal posture and flexibility. Lumbar sagittal flexibility was measured using a modification of the flexicurve technique of Burton.[5] The flexicurve was molded to the midline contour of the lumbar spine in habitual standing posture and in maximal flexion and extension. Tangents were drawn to both flexion, extension, and standing postures at the S-2, L-4, and T-12 levels. The two angles formed by the intersection of these tangents were measured using a protractor to an accuracy of 1°. Based on these measurements, we calculated maximal lumbar extension (T12-S2), maximal lumbar flexion (T12-S2), lumbar standing posture (T12-S2), lumbar ROM (T12-S2), upper segment ROM (T12-L4), and lower segment ROM (L4-S2). The measurements were performed by the same physical therapist (AO), who was familiar with the tests. Test-retest measurements were not done in this study, but the physical therapist had confirmed the repeatability of her measurements in an earlier study.[19]

Statistical Analyses

The chi-squared test, *t*-test, and confidence interval analyses were first used for statistical computations. Factors predicting low back pain were studied by a discriminant model. Height, weight, body mass index, maximal lumbar flexion, maximal lumbar extension, lumbar standing posture, lumbar ROM, lower segment ROM, and upper segment ROM were included in a stepwise discriminant analysis. Analyses were stratified by sex according to our initial hypothesis. For the variables predictive for low back pain we calculated relative risks (RR) and their 95% confidence intervals between the subjects in the highest and lowest tertiles at baseline. The analyses were done by SAS statistical software version 6.08 (SAS Institute Inc., Cary, North Carolina) for microcomputers.

RESULTS

During the 3-year followup, low back pain lasting longer than 1 week was reported by 29 athletes (15 boys and 14 girls) and by 6 nonathletes (3 boys and 3 girls).

The baseline and follow-up subject characteristics are shown in Tables 1 and 2, and means of the subject characteristics for boys and girls with and without low back pain are shown in Table 3.

Among the boys, there were no statistically significant differences in the flexibility measurements of the lumbar spine between athletes and nonathletes at baseline (Table 2). Among girls, the lumbar ROM ($P = 0.014$) and the lower segment ROM ($P = 0.036$) were significantly higher among nonathletes than among athletes, and nonathletes had more lordotic standing posture than athletes at baseline (Table 2).

Among boys, weight and body mass index increased more in subjects with low back pain during followup than among subjects without low back pain (Table 3). Those girls with future low back pain had lower maximal lumbar extension and lower lumbar ROM in the lower segment at baseline (Table 3).

Multivariate Analyses

Among boys, participation in sports ($P = 0.019$) and low maximal lumbar flexion ($P = 0.15$) at the baseline predicted low back pain during the followup in stepwise discriminant analysis. These factors accounted for 11.5% and 4.6% of the variability between the groups with and without low back pain among boys, respectively, explaining together 15.6% of the total variability. Among girls, low lower segment lumbar ROM ($P = 0.0045$), low maximal lumbar extension ($P = 0.029$), and high body weight ($P = 0.11$) at the baseline were predictive of low back pain during the followup (stepwise discriminant analysis). These factors accounted for 9.0%, 5.1%, and 2.7% of the variability between the groups with and without low back pain, respectively, explaining together 30.9% of the total variability among girls.

The boys in the lowest tertile of maximal lumbar flexion at baseline had an RR of 2.5 (95% CI, 0.8 to 8.0) to have future low back pain compared with those in the highest tertile at baseline.

The girls in the lowest tertile of lower segment lumbar ROM at baseline had an RR of 2.6 (95% CI, 1.0 to 6.6) to have future low back pain compared with those in the highest tertile at baseline. The girls in the lowest tertile of maximal lumbar extension at baseline had an RR of 3.4 (95% CI, 1.2 to 10.3) to have future low-back pain compared with those in the highest tertile at baseline. The girls in the highest body weight tertile at baseline had a similar risk (RR 1.0; 95% CI, 0.4 to 2.4) to have future low back pain compared with those in the lowest tertile at baseline.

DISCUSSION

According to our initial hypothesis, low maximal extension of the lumbar spine predicted future low back pain among girl athletes involved in activities that included excess hyperextension. The girls in the lowest tertile of maximal lumbar extension at baseline had over three times higher risk to have future low back pain compared with those in the highest tertile at baseline.

Low back pain patients often have reduced ROM in the lumbar spine and it may be possible to restore the mobility by physical training programs.[8,10] We have recently documented that the physiologic maximum of extension mobility of the healthy lumbar spine of adolescents cannot be increased by training.[24] We analyzed the abnormalities of intervertebral disks and vertebral end plates using magnetic resonance imaging in the girls in our study[12] and there was no association between the mobility measurements of the lumbar spine and the magnetic resonance imaging abnormalities. So, in our young study groups low back pain or degenerative changes at baseline did not explain our findings. Tsai and Wredmark[26] did not find any difference in either posture or sagittal motion of the lumbar spine between former gymnasts and controls.

During adolescence, the occurrence of low back pain increases with age,[14,16] and reasons for and predictors of back pain should be understood to prevent this problem. It has been claimed that low back pain in young athletes often originates in the posterior elements of the lumbar spine.[15] Repeated maximal extension of the back[21] and a number of acute injuries to the low back[12] contribute to the development of the anatomic abnormalities. Among 60 consecutive spinal radiographs taken of each dancer at the beginning of their employment in the Finnish National Ballet, there was spondylolysis in 32% (19 of 60),[22] while the occurrence of spondylolysis among nonathletic subjects is 5% or less. Interestingly, old reports of circus people document that the so-called snake women, who trained regularly for lumbar extension, commonly had serial spondylolysis,[4] which was not found in their colleagues who trained for lumbar flexion regularly.[3]

Other sports than gymnastics and figure skating include specific demands for lumbar spine. The boys in the lowest tertile of maximal lumbar flexion at baseline tended to have a higher risk to have future low back pain compared with those in the highest tertile at baseline. The boy athletes were involved in soccer and ice hockey, both of which require predominantly flexion, lateral bending, and rotation ranges of lumbar motion. However, other specific movements than flexion and extension were outside of our study aim because the heterogeneity of the movement patterns in boy athletes (soccer and ice hockey) and because there are no reliable noninvasive methods to document individual differences in the rotation of the lower lumbar spine. The measurement that we used to characterize lateral bending range of the spine at baseline[13] did not predict future back pain during the 3-year followup (results not shown). Back muscles protect the underlying spine from excessive bending,[1] and this protection is reduced by poor mobility[9] and aggravated further by muscular fatigue. Differences in athletic training most likely explain the sex differences in the risk factors for future low back pain.

In our study, baseline training hours per week did not predict occurrence of low back pain during the 3-year followup. This fact indicates that training hours at baseline did not cause a bias in our study results.[14] Unfortunately, the time interval between the height measurements in our study was too long to investigate how strictly the occurrence of low back pain is associated with the peak growth velocity. The fact that girls tended to report first low back pain at a younger age than boys supports an association between pain and growth spurt. Increased hamstring tightness and low back pain often manifest simultaneously in growing athletes. Because the flexicurve technique measures only lumbar motion, we also measured hamstring tightness[13] in our subjects at baseline and at the 3-year followup. However, baseline hamstring tightness did not predict low back pain during the 3-year followup (results not shown).

We conclude that the low physiologic maximum of lower segment lumbar extension mobility may cause overloading of specific anatomic structures of the low back among athletes involved in sports including frequent maximal lumbar extension and that it predicts future low back pain in these subjects. Repetitive extension maneuvers may also lead to structural changes in the lumbar spine. This knowledge should be incorporated in the planning of the rules of sports and choreography of dance performances.

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