

# Risk Factors for Development of Lower Limb Pain in Adolescents

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**ABSTRACT.** *Objective.* Although many clinicians believe high growth leads to inflexibility, which may lead to lower extremity pain, the only prospective data suggest growth is unrelated to flexibility. However, it is still possible that growth and/or flexibility are related to pain even if they are not related to each other. We investigated the incidence of leg pain in adolescents to determine whether high growth spurt and/or poor flexibility are risk factors for the development of lower extremity pain.

*Methods.* Repeated measures, prospective cohort study of urban high school students aged 12–18. Subjects were measured at baseline and at 6 and 12 months for flexibility of hamstrings and quadriceps and with the sit-and-reach test. Participants completed a detailed questionnaire on recreational activity, occupational activities, psychosocial variables, and musculoskeletal pain.

*Results.* Poor hamstring flexibility (odds ratio 0.99, confidence interval 0.97–1.01), poor quadriceps flexibility (OR 1.01, CI 0.99–1.03), poor sit-and-reach flexibility (OR 0.99, CI 0.99–1.01), and growth (OR 0.93, CI 0.50–1.71) were not related to the development of lower extremity pain. There was an association between lower extremity pain and occupational activities (OR 2.08, CI 1.45–2.98) and poor mental health (per 1 SD change, OR 1.41, CI 1.19–1.67).

*Conclusion.* Neither growth nor flexibility is related to the development of lower extremity pain in adolescents. A poor mental health score and occupational activities may be associated with the development of lower extremity pain. (J Rheumatol 2001;28:604–9)

## Key Indexing Terms:

ADOLESCENCE

LEG PAIN

MUSCULOSKELETAL INJURY

Lower extremity pain is common in adolescence<sup>1</sup>; conditions such as patellofemoral pain syndromes have a reported prevalence of up to 15%<sup>2</sup>. These conditions may limit participation in physical education, sports, or other recreation and lead to an inactive lifestyle later. To develop effective preventive strategies, a more complete understanding of the mechanisms that underlie these conditions is necessary.

One hypothesis for lower extremity pain is that the adolescent growth spurt causes a decrease in flexibility, which leads to pain<sup>3–6</sup>. However, we recently showed that growth does not lead to decreases in flexibility<sup>7</sup>. It remains possible that either growth or flexibility is related to the development of pain, even if they are unrelated to each other. For instance, there is indirect evidence suggesting that inflexibility may be a cause of pain in some populations. In

a randomized trial of military recruits undergoing basic training, regular stretching appeared to decrease injury rate<sup>8</sup>. In 2 other studies, stretching alleviated symptoms in young children with “growing pains”<sup>9</sup> and in elite skaters<sup>10</sup>. However, these 2 studies do not prove that stretching prevents the development of pain because recent research suggests that stretching has an analgesic effect<sup>11,12</sup>. If true, stretching could be used as therapy to alleviate symptoms, but might not prove effective as a preventive strategy.

Although there have been no prospective studies on whether growth results in the development of pain, 3 prospective studies address the issue of inflexibility predicting the development of pain. Knapik, *et al* reported a trend for higher lower limb injury rates associated with hip extensor tightness imbalance in collegiate female athletes<sup>13</sup>. However, the association was limited to an imbalance and not to inflexibility itself. Results from 2 other prospective studies on young athletes suggest that inflexibility is not predictive of injuries<sup>1,14</sup>.

Considering the high prevalence of lower extremity pain in adolescents and the paucity of prospective data, we assessed the incidence of leg pain in a cohort of adolescents to ascertain whether high growth spurt and/or poor flexibility are risk factors for the development of lower extremity pain in adolescents.

## MATERIALS AND METHODS

*Subjects and methods.* A cohort of high school students in Montreal, Quebec, was followed prospectively over a 12 month period to assess the

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incidence of lower limb pain and risk factors for its development. Students in the 7th to 9th grades from 3 schools were evaluated — 2 public inner city schools and one smaller private school. Of 948 eligible subjects who attended the schools in grades that were to be tested, 810 agreed to participate and were present on the first day of testing (85.4%). In accordance with the laws of the province of Quebec, all students (and parents of those under the age of 14 years) gave signed informed consent for the study. Data were collected 3 times over the year: at inception (fall of 1995), 6 months later (spring of 1996), and at 12 months (fall of 1996). At each time students were asked to complete a self-administered questionnaire that addressed lifestyle and musculoskeletal health. We also measured their height, weight, and lower limb flexibility during physical education class. This study was approved by the Research and Ethics Committee of the SMBD-Jewish General Hospital, McGill University, and the Research Committee of the Montreal Catholic School Commission.

**Outcome.** The outcome was defined as lower limb pain occurring at a frequency of at least once a week within the past 6 months. It was felt that this definition of pain would reflect a more serious episode of lower limb pain as opposed to transient, inconsequential pain. A similar classification was employed by Mikkelsen, *et al* using a 3 month recall<sup>15</sup> and by Brattberg using a 6 month recall<sup>16,17</sup> in their studies of adolescent pain. Lower limb pain was positive if the respondent reported pain in at least one site (hip, knee, lower leg, foot, and ankle).

**Explanatory variables.** The explanatory variables included flexibility measurements and lifestyle factors. Flexibility was measured with 3 different reliable tests, as described<sup>7</sup>. Briefly, quadriceps flexibility was evaluated in degrees as knee flexion range of movement in the prone position (quadriceps angle) using a standard goniometer<sup>18</sup>. We assessed hamstring flexibility as the goniometric measurement of the popliteal angle<sup>19</sup>. For both quadriceps and hamstring flexibility, a smaller angle indicated better flexibility. Sit-and-reach (a measure of toe-touch flexibility) was tested with a standard sit-and-reach box and measured in centimeters. The grade was negative if the student could not touch his/her toes, 0 if the toes were reached, and positive when the student reached beyond the toes<sup>20–24</sup>. To increase reliability, each flexibility measure was assessed by the same evaluator (a sport medicine physician or a physiotherapist) at all 3 times<sup>18,25,26</sup>.

Lifestyle factors included sport participation and occupational activities. Subjects were asked to record whether they spent < 5 hours, 5–10 hours, or > 10 hours for each sport or type of occupational activity. Sport participation was then defined as a continuous variable, graded as the sum of the time categories (< 5 h = 1, 5–10 h = 2, > 10 h = 3) spent in all activities over the past 6 months. To control for different intensities of exercise, we also ran a parallel analysis in which activities were categorized according to their respective metabolic equivalent levels<sup>27</sup>. We used the mean number of hours for a particular category as the duration (e.g., 5–10 h per week was considered as 7.5 h per week).

Occupational activity was also defined in a number of ways. First, occupational activity was also defined dichotomously as having worked in the past 6 months or not. The sum of the time categories (1–10 h/week = 1, 11–20 h/week = 2, > 20 h/week = 3) spent working in all jobs over the past 6 months was defined as a continuous variable depicting frequency. In addition, work was categorized as either childcare, blue-collar type work, or white-collar type work (reference category: not working at all).

Mental health status was determined by the 5 item Mental Health Index from the Short-Form 36 (5 item MHI), which is designed to measure mood and anxiety over the previous week<sup>28</sup>. This variable was measured concurrently with the outcome. Finally, smoking has been associated with musculoskeletal pain and overall health in the adolescent population<sup>29</sup>. We included it in our analysis as a dichotomous variable (i.e., at inception, currently smoking or not).

**Analysis.** Analysis consisted of descriptive statistics, calculation of cumulative incidence of pain in the lower extremity by site and time interval, as well as a risk factor analysis using the generalized estimating equations

(GEE) model. The GEE model accounts for intrasubject correlation among repeated measurements on the same subject, and improves power compared to treating each 6 month period separately. The time-varying dichotomous outcome of lower limb pain was modeled as a function of the time-varying risk factors of growth spurt and flexibility, adjusted for age, sex, smoking, and the time-varying covariates of activity participation (sports and occupational activities), smoking, and mental health status. High growth spurt was defined as having grown > 5 cm in a 6 month period<sup>30</sup>. Flexibility measurements entered into the model were taken 6 months earlier than the determination of lower extremity pain. This was done to ensure that flexibility preceded the experience of lower extremity pain and was not influenced by the pain. Similarly, pain had to be absent at the onset of each 6 month period. Thus we excluded subjects who had lower limb pain within the 6 months prior to inception (prevalent cases: data obtained from questionnaires), but included them in the analysis for the second interval if they did not have pain over the first 6 month period (i.e., 6 months pain-free). Students who were pain-free at inception but developed pain during the first 6 month period were censored at 6 months. All analyses were done using SAS version 6.12 software (SAS Institute Inc., Cary, NC, USA)<sup>31</sup>.

## RESULTS

**Methodological results.** Of the 810 subjects who began the study, 502 students participated at all 3 times in the evaluations (62% of those who initially agreed) and these were used for the analysis. Subjects who were lost to followup were similar to those who remained in the study with respect to sex, age, weight, height, physical activity, and lower limb pain status at inception. However, smokers made up 36.4% of the group lost to followup, but only 19.7% of the study group (Table 1).

The main outcome was the 6 month measure of substantial lower extremity pain, a subjective response. To validate these responses, we compared the correspondence between responses of having had lower limb pain in the past 6 months and taking medication in the past month for this problem. Of 38 students who took medication for lower limb pain at the first evaluation, 33 (85%) said that they had lower limb pain in the past 6 months. At the 6 month and 12 month evaluations, the figures were 91% and 86%, respectively, which suggests moderate to high consistency.

Table 1. Comparison of subjects studied and those lost to followup (mean or percentage, ± SE).

	Included in Study, n = 502	Lost to followup, n = 308
Male, %	52.6 (2.2)	56.5 (2.8)
LEP1, %*	38.8 (2.2)	43.2 (2.8)
Smoker, yes, no %	19.7 (1.8)	36.4 (2.7)
Age, yrs	13.8 (0.1)	14.4 (0.1)
Weight, kg	53.0 (0.6)	55.5 (0.8)
Height, cm	158.2 (0.5)	160.8 (0.5)
Physical activity**	4.2 (0.2)	3.9 (0.2)
Occupational activities†	1.2 (0.1)	1.5 (0.1)

\*LEP1 refers to those who reported having substantial lower extremity pain at inception.

\*\*Sum of categories of number of hours spent in physical activities.

†Sum of categories of number of hours spent in occupational activities.

**Descriptive results.** A description of the cohort's physical measures is presented in Table 2. Growth was higher over the second interval (i.e., spring to fall) than in the first interval (fall to spring). Sit-and-reach flexibility was highest at 6 months, whereas hamstring and quadriceps measures remained relatively stable over the 3 times.

Cumulative incidence of lower extremity pain is illustrated in Figure 1. For all sites, the incidence of pain was higher in the first interval (i.e., fall to spring). The foot and ankle and the knee were the most common sites of pain. The 6 month incidence of lower limb pain at least 1/week was 21% in the first interval (64 among 307 who were pain-free at inception) and 16% in the second interval (51 among 330 who were pain-free at 6 months). The cumulative annual incidence of lower limb pain at least 1/week was 30%.

**Risk factor analysis.** Results of the GEE analysis are displayed in Tables 3 (overall lower extremity pain) and 4 (site-specific lower extremity pain). Neither high growth nor any of the flexibility measures were significantly associated with the development of overall lower limb pain. Similarly, high growth and poor flexibility were not risk factors for development of pain at the individual sites (hip, knee, leg or foot, and ankle). These findings were robust. There were no significant changes in results whether growth

Table 2. Descriptive results: physical measures (mean  $\pm$  SD).

Variable	Inception	6 Months	12 Months
Growth, cm*	—	1.6 (2.1)	2.8 (2.1)
Sit-and-reach test, cm	2.3 (8.2)	3.7 (8.7)	2.4 (9.2)
Hamstrings flexibility, degrees	41.6 (10.6)	40.3 (11.2)	38.2 (11.5)
Quadriceps flexibility, degrees	48.5 (10.7)	46.5 (9.6)	46.2 (9.6)

\*Refers to growth over the first and second 6 month periods.

Table 3. Risk factors for lower extremity pain\* (GEE analysis).

Variable	Adjusted OR (95% CI)
Growth	
High growth	0.93 (0.50–1.71)
Flexibility	
Poor hamstring flexibility**	0.99 (0.97–1.01)
Poor quadriceps flexibility**	1.01 (0.99–1.03)
Poor sit-and reach flexibility**	0.99 (0.97–1.01)
Covariates	
Poor MHI score	1.02 (1.01–1.03)
Occupational activities <sup>†</sup>	2.08 (1.45–2.98)
Activity <sup>‡</sup>	0.99 (0.98–1.02)
Initial height, cm	1.00 (0.97–1.02)
Age, yrs	0.99 (0.84–1.17)
Female sex	0.90 (0.58–1.38)
Smoking, yes/no	1.35 (0.93–1.97)

\*Refers to those who reported having substantial lower extremity pain.

\*\*Odds ratio refers to each degree lost in hamstring and quadriceps flexibility, and to each cm lost in the sit-and-reach test (i.e., > 1 means increased risk).

<sup>†</sup>Sum of categories of number of hours spent in occupational activities.

<sup>‡</sup>Sum of categories of number of hours spent in physical activities.

MHI: 5 item Mental Health Index.

was entered as a continuous, ordinal, or dichotomous variable; whether activity was categorized as sum of categories or metabolic equivalents; or whether work was defined as a continuous, categorical (blue-collar, white-collar, or child-care categories), or dichotomous variable (data not shown).

Although growth and flexibility are unrelated to the development of pain, our results do suggest that students who worked were more likely to develop lower extremity pain (OR 2.08, 95% CI 1.45–2.98). In addition, those with a

Table 4. Risk factors for hip, knee, leg, and foot and ankle pain (GEE analyses)\*.

Variable	Hip	Knee	Leg	Foot & Ankle
Growth				
High growth	0.50 (0.12–2.18)	1.17 (0.53–2.59)	1.57 (0.65–3.81)	1.37 (0.75–2.49)
Flexibility				
Poor hamstring flexibility**	0.96 (0.91–1.03)	1.00 (0.98–1.02)	0.99 (0.96–1.01)	1.02 (0.99–1.05)
Poor quadriceps flexibility**	1.01 (0.97–1.06)	1.00 (0.98–1.02)	1.01 (0.99–1.03)	1.02 (0.99–1.05)
Poor sit-and-reach flexibility**	1.01 (0.95–1.07)	0.99 (0.96–1.01)	1.01 (0.98–1.04)	0.98 (0.95–1.02)
Covariates				
Poor MHI score	1.00 (0.98–1.03)	1.02 (1.01–1.03)	1.02 (1.01–1.04)	1.01 (0.99–1.03)
Occupational activities <sup>†</sup>	2.17 (0.67–7.00)	1.96 (1.28–2.98)	1.49 (0.78–2.87)	0.97 (0.78–1.21)
Activity <sup>‡</sup>	1.02 (0.96–1.08)	0.99 (0.95–1.04)	1.01 (0.96–1.00)	0.98 (0.93–1.02)
Initial height, cm	1.03 (0.98–1.08)	1.02 (0.99–1.05)	1.02 (0.99–1.06)	0.98 (0.94–1.01)
Age, yrs	0.82 (0.54–1.23)	0.97 (0.80–1.19)	1.12 (0.89–1.42)	0.92 (0.73–1.16)
Female sex	0.85 (0.35–2.01)	1.07 (0.65–1.78)	1.03 (0.53–1.99)	0.71 (0.40–1.24)
Smoking, yes/no	1.70 (0.83–3.41)	1.36 (0.89–2.09)	0.95 (0.56–1.61)	1.60 (0.98–2.59)

\*Refers to those who reported having substantial pain.

\*\*Odds ratio refers to each degree lost in hamstring and quadriceps flexibility, and to each cm lost in the sit-and-reach test (i.e., > 1 means increased risk).

<sup>†</sup>Sum of categories of number of hours spent in occupational activities.

<sup>‡</sup>Sum of categories of number of hours spent in physical activities.

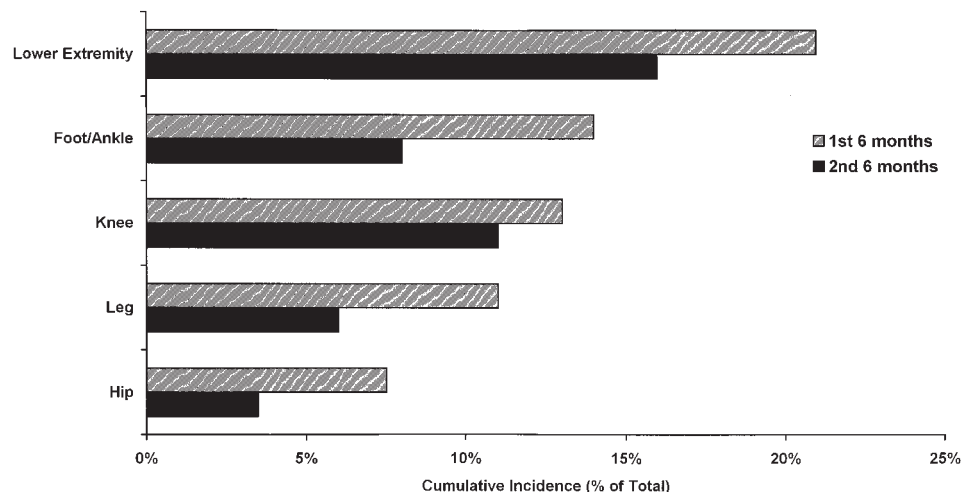


Figure 1. Cumulative incidence of lower extremity, hip, knee, leg, and foot and ankle pain occurring at least once per week for the first and second 6 month periods.

lower mental health score were more likely to develop lower limb pain (Table 3). Although the estimated odds ratio is 1.02, this is per one unit increment of mental health score. For an increment of one standard deviation of this score (i.e., 17 units) the estimated odds ratio is 1.41 (CI 1.19–1.67). However, mental health score was assessed concurrently with outcome (as it refers to how the subject felt in the past week), because we had not asked about mental health at inception. Thus in this analysis we do not know if mental health preceded or followed pain status. To study whether previous mental health had an effect on lower limb pain, we repeated the analysis using only the exposure data from the 6 month time period (which included the 5 item MHI) and the outcome from the 12 month period. The results were the same: poor mental health score had an OR of 1.40 (CI 1.18–1.95).

To control for socioeconomic status, we also reanalyzed the data stratified on school (public vs private) as a proxy. The conclusions were unaffected (data not shown).

## DISCUSSION

We found an annual incidence of 30% for lower extremity pain. This is considerably higher than the 7% reported by Mikkelsen, *et al*<sup>15</sup>. However, the latter cohort comprised prepubescent students, whereas our subjects were peripubescent. Our results are similar to those of Knapik and associates, who reported a cumulative incidence of 30% in a cohort of infantry soldiers<sup>32</sup>, and the control group in an intervention study by Hartig and Henderson (29% incidence of lower extremity injury)<sup>8</sup>. As for the most common sites of lower extremity pain, both Knapik, *et al*<sup>32</sup> and Schmidt-Olsen, *et al*<sup>5</sup> reported similar patterns to those we found, with foot and ankle and knee having the highest frequency, followed by lower leg and hip.

Our results indicate that high growth and diminished flexibility are not risk factors for the development of lower extremity pain in adolescents. These results go against the untested hypothesis proposed by some investigators that rapid growth leads to inflexibility that leads to pain<sup>6</sup>. On the other hand, our results compare well with Maffulli and associates<sup>1</sup>, who found that flexibility is not related to subsequent injury in adolescent elite athletes. Further, Orchard, *et al*<sup>14</sup> found similar results for sit-and-reach flexibility in Australian footballers. Our study extends these results to include not only “injuries,” but any significant pain that is present at least 1/week even if there is no injury per se.

Although inflexibility may not be a risk factor for lower extremity pain, Hartig and Henderson<sup>8</sup> did find that soldiers who underwent hamstring stretching had lower frequency of injury. The problem with this study was that the control group was less flexible at baseline and no data were presented on previous injuries. Because a history of lower extremity injury is likely to be associated with poorer flexibility, it is possible that the control group was already at a higher risk for injury, independent of the stretching intervention. Another possible interpretation of these results is that stretching prevents injury, but through a mechanism that is different from flexibility. For example, “stretch induced hypertrophy” refers to the hypertrophy that occurs when animal muscle is stretched 24 hours/day for several days<sup>33–35</sup>. It is possible that stretch induced hypertrophy could occur with shorter durations of stretching carried over longer periods of time (e.g., 5 minutes/day for 4 weeks). If true, the increase in tissue strength would explain the reduced injury risk and changes in flexibility would simply be an associated factor with no causal relationship. Thus, Hartig and Henderson’s study is an important step to increasing our understanding of the relation between



stretching and injury risk. Future studies should control for the known risk factor of previous injury, and hypothesized risk factors of age, fitness level, etc.

The finding that mental health score and occupational activities were associated with lower extremity pain supports findings in the literature. In cross sectional studies, students who were more depressed were found to be more likely to complain of pain. Unfortunately, it is unclear whether the depression preceded the pain in such designs<sup>36-38</sup>. Although our results are also cross sectional for mental health status, a secondary analysis using prospective data obtained during the second 6 month period found that low mental health scores at 6 months were associated with a higher occurrence of pain at 12 months. This suggests that low scores on the 5 item Mental Health Index are predictive for the development of lower extremity pain.

Students who worked were also more likely to develop lower limb pain, particularly in the knee. The cumulative incidence of lower limb pain was higher in the first interval than in the second. Because this first interval represents the majority of the school year whereas the second interval includes the summer vacation time, it is possible that the increased stress associated with school or concomitant work<sup>39</sup> may increase the risk of development of lower limb pain. That the same pattern was observed for each specific site of injury suggests that the finding is unlikely to have occurred by chance.

The absence of any correlation between physical activity and lower extremity pain is noteworthy. Adolescents who took part in physical activity were not more likely to develop lower limb pain. In addition, the incidence of lower limb pain in our cohort was similar to that from a military cohort<sup>8</sup>, where activity would be expected to be much greater. Together, these findings suggest that regular physical activity does not appear to be a risk factor for development of lower extremity pain. This would imply that any apparent increased injury risk associated with activity is balanced by an increased risk of developing musculoskeletal pain due to inactivity.

As in any epidemiological study, the possibility of bias obscuring the true association exists. There were 308 students out of the original 810 who were lost to followup. This group did not differ significantly from the 502 who were followed at all 3 times with respect to sex or lower extremity pain status at inception. The "lost group" was slightly older, and included considerably more smokers. Although we did not find smoking to be significantly associated with lower limb pain, the odds ratio point estimate was 1.35. If smoking is truly a risk factor for development of lower limb pain then it is possible that our finding is an underestimate.

Another possible source of bias is misclassification. Outcome (presence of lower limb pain at least 1/week) was based on self-reports. Our results with respect to frequency

of lower limb pain are similar to those of lower extremity injury in 2 studies of military recruits<sup>8,32</sup>, which suggests recall bias was minimal. Further, Aaron, *et al*<sup>40</sup> showed that adolescents have good 12 month recall with respect to physical activity, and we asked only about the previous 6 months. Even if there were problems with recall over a 6 month period, exposure was measured 6 months prior to lower limb pain status. Thus it is unlikely that recall of outcome differed within the exposure categories, and therefore unlikely that results were biased. We used a 5 item mental health score. This score is as good as the 18 item Mental Health Inventory and the 30 item General Health Questionnaire, and better than the 28 item Somatic Symptom Inventory for the detection of depression, affective disorders, and anxiety<sup>41</sup>.

It is possible that some unmeasured confounding variable could bias the results. One possible confounder is socioeconomic status. However, a stratified analysis based on school (public vs private) as a proxy for socioeconomic status did not affect our conclusions.

Our findings indicate that lower limb pain at least 1/week is common in teenagers, with a higher incidence in the fall to spring interval than the spring to fall period. Foot and ankle and knee pain were the most common sites of pain. High growth spurt, hamstrings, quadriceps, and sit-and-reach flexibility were not implicated as risk factors for development of lower extremity pain. However, adolescents who participated in occupational activities and had poorer mental health status were more likely to develop lower extremity pain. It is possible that lower limb pain is more common during the school year because of additional stress at that time. If so, stress reduction strategies may be useful for teenagers who are working or appear to have a poor mental health profile.

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