Dose–response relationship between sports activity and musculoskeletal pain in adolescents

The Harvard community has made this article openly available. Please share how this access benefits you. Your story matters

Citation

Published Version
doi:10.1097/j.pain.0000000000000529

Citable link
http://nrs.harvard.edu/urn-3:HUL.InstRepos:27662319

Terms of Use
This article was downloaded from Harvard University’s DASH repository, and is made available under the terms and conditions applicable to Other Posted Material, as set forth at http://nrs.harvard.edu/urn-3:HUL.InstRepos:dash.current.terms-of-use#LAA
1. Introduction

Musculoskeletal pain (MSP) is a common health problem among adolescents, with a prevalence ranging from 4% to 40%. In school-aged youth, MSP is associated with not only functional disability and lower quality of life but also future risk of MSP during adulthood. Musculoskeletal pain can be severe enough to require prescription pain medications, which can lead to opioid misuse among youth. Pain medications were used for non-medical reasons by 4.6% of U.S. adolescents in 2013. Physical activity, including organized sports, has multiple health benefits but may also increase the risk of developing musculoskeletal pain (MSP). However, the relationship between physical activity and MSP has not been well characterized. This study examined the dose–response relationship between sports activity and MSP among adolescents. Two school-based serial surveys were conducted 1 year apart in adolescents aged 12 to 18 years in Unnan, Japan. Self-administered questionnaires were completed by 2403 students. Associations between time spent in organized sports activity and MSP were analyzed cross-sectionally (n = 2403) and longitudinally (n = 374, students free of pain and in seventh or 10th grade at baseline) with repeated-measures Poisson regression and restricted cubic splines, with adjustment for potential confounders. The prevalence of overall pain, defined as having pain recently at least several times a week in at least one part of the body, was 27.4%. In the cross-sectional analysis, sports activity was significantly associated with pain prevalence. Each additional 1 h/wk of sports activity was associated with a 3% higher probability of having pain (prevalence ratio = 1.03, 95% confidence interval = 1.02–1.04). Similar trends were found across causes (traumatic and nontraumatic pain) and anatomic locations (upper limbs, lower back, and lower limbs). In longitudinal analysis, the risk ratio for developing pain at 1-year follow-up per 1 h/wk increase in baseline sports activity was 1.03 (95% confidence interval = 1.02–1.05). Spline models indicated a linear association (P < 0.001) but not a nonlinear association (P ≥ 0.45). The more the adolescents played sports, the more likely they were to have and develop pain.

Keywords: Exercise, Low back pain, Epidemiology, Cumulative trauma disorders, Injuries
student age 15-18 years) in Uname, population 43,520, area
553.4 km²), Shimane, Japan, participated in this study. In
October 2008, and again in October 2009, identical self-
administered questionnaires were distributed to all the students
in the participating schools (2267 and 2212 students in 2008 and
2009, respectively) and returned through the schools. Responses
from students who received special needs education and questionnaires with invalid responses (blank forms) were
excluded. In total, 1783 (76.5%) of the students in 2008 and
1897 (85.5%) of the students in 2009 answered the question-
naires. An explanation of the students’ right to decline to answer
any question and general information about the study were
provided in a letter to the parents or guardians of the students that
was included with the questionnaire. Students signed the
questionnaire and returned it in an unlabeled envelope. Individual
student’s answers were not provided to their teachers or sports
coaches. This study was approved by the research ethics
committee of the Physical Education and Medicine Research
Center UNNAN (H19-7-23-5).

We conducted cross-sectional and longitudinal analyses of the
data collected. In the cross-sectional analysis, data from both
years (2008 and 2009) were used simultaneously; thus, 3680
records from 2403 students, which included both single and
repeated measures, were included. Longitudinal analysis was
conducted to estimate the risk of developing MSP. Data from 374
students who had filled out the questionnaires in both years and
did not suffer from MSP at the time of first assessment were
included in the longitudinal analysis. Only students in seventh or
10th grade at baseline (2008) were included in the longitudinal
analysis because students in ninth or 12th grade stopped
participating in organized sports between July and March to
prepare for examinations and graduation, and thus, the
assessment of their exposure–outcome relationship was con-
sidered incomplete. The inclusion scheme for the data in the
analyses is provided in Supplemental Figure S1 (Supplemental
Digital Content 1, available online as Supplemental Digital
Content at http://links.lww.com/PAIN/A247). A cross-sectional
analysis that excluded ninth and 12th grade students was also
conducted as a sensitivity analysis.

2.2. Measures

Information on sex, age, weight, and height (converted into body
mass index [BMI], in kilograms per square meter), participation in
organized sports (in hours per week), sleep time (hours per day
from time in until time out of bed), and screen time (hours per week,
total time spent watching TV and gaming on weekdays and
weekends) were obtained from the questionnaires. Organized
sports activity was defined as sports activities that took place after
school programs on weekdays and/or weekends or activities
that were organized by sports clubs. All students participated in
routine physical education throughout the year; this was not
included as time spent playing organized sports. For students
who participated in organized sports, the questionnaire also
asked about the type of sport played. Only 11 students reported
participation in multiple types of sports; these students
reported the weekly time spent participating in their main
sports activity.

To check the test–retest reliability of the weekly organized
sports time, 62 students in eighth grade (34 male and 28 female
participants) aged 13 to 14 years were asked to answer the
questionnaire twice 7 days apart in February 2009. Data from
these students were not included in the longitudinal analysis. The
intraclass correlation coefficient had an acceptable value (0.85).

2.3. Pain

Musculoskeletal pain was assessed using a questionnaire (see
eQuestionnaire, Supplemental Digital Content 2, available online
as Supplemental Digital Content at http://links.lww.com/PAIN/ A247). Students were considered to suffer from MSP if pain was
present recently at least several times a week in at least one part
of the body. Musculoskeletal pain locations included the neck,
upper limbs, chest, upper back, lower back, buttocks, and lower
limbs. In addition, we differentiated types of pain by cause
(traumatic or nontraumatic) based on the students’ questionnaire
responses. The test–retest reliability was also tested in the
aforementioned reliability study and found to be acceptable
(Cohen kappa for pain in any location = 0.67). After this reliability
test, the same students underwent an agreement test (criterion
validity test) comprising a face-to-face interview with health
professionals trained by an experienced orthopedist. The Cohen
kappa was 0.52, indicating moderate agreement.

2.4. Statistical analyses

In the cross-sectional analysis, the overall prevalence of pain at
any location was compared across different levels of sports
participation by estimating prevalence ratios (PRs) and their 95%
confidence intervals (CIs) using Poisson regression; generalized estimating equations were used to
account for the correlation within individuals. In the longitudinal
analysis, the risk of developing MSP was determined by
estimating risk ratios (RRs) and 95% CIs using Poisson
regression. Time spent in sports activity was evaluated both
continuously and categorically. Tertiles within students engaged
in organized sports activity were used as cutpoints, and students
who did not participate in organized sports (0 h/wk) were the
reference category. To test linearity, sports activity time was also
analyzed as a continuous variable (crude and quadratic,
separately). Cross-sectional analysis was also performed for the
different causes of MSP (traumatic and nontraumatic) and for its
different locations (upper limbs, lower back, and lower limbs).
These 3 locations were selected based on their higher MSP
prevalence than other locations. In addition, the cross-sectional
analysis was conducted after stratification by 10 different sports.
Models were adjusted for sex, age, BMI, sleep length, screen
time, and school. Body mass index, sleep length, and screen time
were treated as categorical variables and divided into tertiles
within each grade. School was included in the model as a fixed
effect to adjust for all school (cluster) level confounders regardless
of whether they were measured or not. For the longitudinal
analysis, school was included as a determinant of covariance
structure because the sample size was too small to estimate
parameters for different schools.

Continuous associations between the time spent playing
sports and the prevalence or overall risk of pain were estimated
without assuming linearity by fitting restricted cubic spline
models, with the knots corresponding to the 25th, 50th, and
75th percentiles of sports activity time (13.5, 16, and 20.5 h/wk
for the prevalence; 13, 16, and 20 for the risk). Sports activity
time was winsorized at the 99th percentile (34.5 h/wk for the
prevalence; 30 for the risk). The covariates were the same as
those evaluated in the Poisson models. The PRs and RRs were
presented; average probabilities (prevalence and risk) of having or
developing pain were also predicted over the range of time spent
playing sports.

We also assessed whether excess sports activity was
particularly associated with MSP (overall and location-specific)
among heavier students because overweight adolescents may experience greater impacts of physical activity on MSP than lean adolescents. This interaction was tested by modeling the interaction between sports activity and BMI for pain prevalence and by examining the joint categories of BMI and sports activity.

Missing information, ranging from 0.1% for sex to 5.7% for BMI, was processed using multiple imputation (n datasets = 10) under the missing at random assumption. Each imputation was based on regression models of the analyzed variables. The 10 imputed data sets were analyzed independently and combined for inference, accounting for the variability of imputation. To calculate the pain prevalence, available cases without missing values on pain outcomes were used.

For the sensitivity analyses, the analyses were repeated for complete cases only (1498 cross-sectional; 281 longitudinal). In addition, cross-sectional analyses were repeated excluding students in the ninth or 12th grade, using (1) 2458 records from 1920 students (students could contribute >1 record) and (2) data from a single measurement for each of 1816 students. Analyses (2-sided $\alpha < 0.05$) were performed using SAS version 9.3 and STATA version 13.1.

3. Results

Table 1 presents the baseline participant characteristics before multiple imputation. Female (84.5%) and junior high school (87.1%) students had higher response rates compared with male (79.6%) or high school (76.3%) students (both $P < 0.001$). Of the 2403 participants included in the cross-sectional analysis, 51.8% were females. Students had a mean (SD) age of 14.5 (1.8) years. The mean (SD) time spent in organized sports activity was 16.9 (5.7) h/wk for the 1067 (45.3%) students who participated in organized sports. The upper 5% of participants spent $\geq 27.0$ h/wk (95th percentile) in sports activity.

In total, 634 (27.4%) students had MSP, and nontraumatic pain was more prevalent (509 cases, 22.3%) than traumatic pain (129, 5.8%). Figure 1 illustrates the prevalence of pain by location. The lower limbs were the most commonly affected (360, 15.4%) followed by the upper limbs (224, 9.5%) and the lower back (202, 8.5%). In the longitudinal analysis, 82 (22.7%) students who were pain-free at baseline experienced pain at the 1-year follow-up. These data, stratified by MSP locations and causes, can be found in Table S1 (Supplemental Digital Content 3, available online as Supplemental Digital Content at http://links.lww.com/PAIN/A247).

3.1. Cross-sectional analyses

Cross-sectional analyses showed that sports activity and pain prevalence had a significant linear association; students who spent the most time engaged in sports activity ($\approx 18.5$ h/wk) experienced a 2-fold greater rate of pain than students who did not participate in organized sports after adjustment for covariates (Table 2). The test for linearity was significant ($P < 0.001$ for linear; $P = 0.40$ for quadratic); each additional 1 h/wk of sports activity was associated with a 3% higher probability of having pain (PR [95% CI] = 1.03 [1.02-1.04]). Similarly significant linear associations were found in the cause- and location-specific analyses. The spline model also showed a linear association between sports activity and pain prevalence (Fig. 2A). The test for nonlinearity was not significant ($P = 0.95$). In addition, 40% of students were predicted to have pain when they played sports for 21.8 h/wk (Fig. 3A).

### Table 1

**Baseline characteristics of study participants in Shimane, Japan, 2008 to 2009.**

<table>
<thead>
<tr>
<th></th>
<th>Cross-sectional analysis (n = 2403)*</th>
<th>No pain (n = 1676)</th>
<th>Pain (n = 634)</th>
<th>Longitudinal analysis (n = 374)†</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sex, female %</strong></td>
<td>1244, 51.8</td>
<td>899, 53.4</td>
<td>297, 46.9</td>
<td>207, 55.4</td>
</tr>
<tr>
<td><strong>Age, y</strong></td>
<td>14.5 (1.8)</td>
<td>14.7 (1.8)</td>
<td>14.3 (1.8)</td>
<td>13.8 (1.6)</td>
</tr>
<tr>
<td><strong>Body mass index, kg/m²</strong></td>
<td>19.6 (2.7)</td>
<td>19.6 (2.7)</td>
<td>19.6 (2.7)</td>
<td>19.0 (2.6)</td>
</tr>
<tr>
<td><strong>Sleep length, h/d</strong></td>
<td>7.4 (1.0)</td>
<td>7.4 (1.0)</td>
<td>7.5 (1.0)</td>
<td>7.6 (0.9)</td>
</tr>
<tr>
<td><strong>Screen time, h/wk</strong></td>
<td>21.5 (12.1)</td>
<td>21.4 (12.1)</td>
<td>21.7 (12.0)</td>
<td>20.8 (10.8)</td>
</tr>
<tr>
<td><strong>Organized sports activity, %</strong></td>
<td>1067, 45.3</td>
<td>643, 39.1</td>
<td>392, 63.0</td>
<td>213, 58.8</td>
</tr>
<tr>
<td><strong>Mean (SD), h/wk‡</strong></td>
<td>16.9 (5.7)</td>
<td>16.5 (5.3)</td>
<td>17.5 (6.3)</td>
<td>16.5 (5.0)</td>
</tr>
<tr>
<td><strong>Sports type</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Individual sports, N</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Track and field</td>
<td>42</td>
<td>25</td>
<td>15 (37.5)§</td>
<td>7</td>
</tr>
<tr>
<td>Soft tennis</td>
<td>75</td>
<td>59</td>
<td>15 (20.3)§</td>
<td>19</td>
</tr>
<tr>
<td>Table tennis</td>
<td>32</td>
<td>29</td>
<td>3 (9.4)§</td>
<td>7</td>
</tr>
<tr>
<td>Badminton</td>
<td>46</td>
<td>26</td>
<td>17 (39.5)§</td>
<td>9</td>
</tr>
<tr>
<td>Kendo</td>
<td>45</td>
<td>25</td>
<td>20 (44.4)§</td>
<td>3</td>
</tr>
<tr>
<td>Judo</td>
<td>31</td>
<td>16</td>
<td>14 (46.7)§</td>
<td>4</td>
</tr>
<tr>
<td>Karate</td>
<td>13</td>
<td>9</td>
<td>3 (25.0)§</td>
<td>7</td>
</tr>
<tr>
<td>Swimming</td>
<td>1</td>
<td>0</td>
<td>1 (100.0)§</td>
<td>0</td>
</tr>
<tr>
<td><strong>Team sports, N</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseball</td>
<td>165</td>
<td>97</td>
<td>65 (40.1)§</td>
<td>29</td>
</tr>
<tr>
<td>Softball</td>
<td>102</td>
<td>56</td>
<td>42 (42.9)§</td>
<td>20</td>
</tr>
<tr>
<td>Basketball</td>
<td>106</td>
<td>49</td>
<td>53 (52.0)§</td>
<td>14</td>
</tr>
<tr>
<td>Soccer</td>
<td>41</td>
<td>24</td>
<td>15 (38.5)§</td>
<td>7</td>
</tr>
<tr>
<td>Volleyball</td>
<td>197</td>
<td>109</td>
<td>82 (42.9)§</td>
<td>41</td>
</tr>
<tr>
<td>Other</td>
<td>2</td>
<td>2</td>
<td>0 (0)§</td>
<td>0</td>
</tr>
</tbody>
</table>

Values are numbers and percent values for categorical variables and mean (SD) for continuous variables. Sample sizes (denominators) of number counts vary due to missing values.

* Single data (the first response data) for each student.

† Limited to sports players (1067 [45.3%] for the cross-sectional analysis; 213 [58.8%] for the longitudinal analysis).

§ Pain prevalence (%) within sports type.
In the cross-sectional analyses stratified by sports type, most sports had a significant linear association between activity time and pain (PR = 1.03-1.05 per h/wk). However, certain sports with small sample sizes, especially soft tennis and table tennis, had lower pain prevalences (20.3% and 9.4%, respectively; Table 1) and no significant associations between time and pain (P for linearity >0.75; see Table S2, Supplemental Digital Content 4, available online as Supplemental Digital Content at http://links.lww.com/PAIN/A247).

The interaction between BMI and sports activity was not significantly associated with the overall pain prevalence (P = 0.95); however, this interaction was significant for upper limb pain (P = 0.048) but not pain at other locations (P > 0.5). In the further stratified analysis, the PRs for upper limb pain were higher across the sports activity levels among participants with higher BMIs (Figure S2, Supplemental Digital Content 5, available online as Supplemental Digital Content at http://links.lww.com/PAIN/A247).

Figure 1. Pain prevalence at various anatomic locations among adolescents (n = 2403).

Table 2

<table>
<thead>
<tr>
<th>Organized sports activity</th>
<th>PR or RR per 1 h/wk</th>
<th>P for linearity</th>
</tr>
</thead>
<tbody>
<tr>
<td>No sports</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity range, h/wk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall pain, case/n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR (95% CI)</td>
<td>1 (Ref)</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1.0-14.0</td>
<td></td>
</tr>
<tr>
<td>397/2007 (19.8)</td>
<td>182/501 (36.3)</td>
<td>163/451 (36.1)</td>
</tr>
<tr>
<td>1.66 (1.37-2.02)</td>
<td>1.72 (1.41-2.09)</td>
<td>2.17 (1.79-2.62)</td>
</tr>
<tr>
<td>205/485 (42.3)</td>
<td>1.03 (1.02-1.04)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Cause-specific</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Traumatic, case/n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR (95% CI)</td>
<td>1 (Ref)</td>
<td></td>
</tr>
<tr>
<td>70/1965 (3.6)</td>
<td>36/485 (7.4)</td>
<td>29/438 (6.6)</td>
</tr>
<tr>
<td>1.85 (1.18-2.91)</td>
<td>1.73 (1.09-2.75)</td>
<td>2.61 (1.69-4.04)</td>
</tr>
<tr>
<td>36/462 (7.8)</td>
<td>1.04 (1.02-1.05)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Nontraumatic, case/n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR (95% CI)</td>
<td>1 (Ref)</td>
<td></td>
</tr>
<tr>
<td>331/1988 (16.7)</td>
<td>148/491 (30.1)</td>
<td>138/445 (31.0)</td>
</tr>
<tr>
<td>1.62 (1.31-2.00)</td>
<td>1.70 (1.38-2.10)</td>
<td>2.05 (1.67-2.52)</td>
</tr>
<tr>
<td>169/475 (35.6)</td>
<td>1.03 (1.02-1.04)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Location-specific</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper limb, case/n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR (95% CI)</td>
<td>1 (Ref)</td>
<td></td>
</tr>
<tr>
<td>137/2049 (6.7)</td>
<td>46/506 (9.1)</td>
<td>55/460 (12.0)</td>
</tr>
<tr>
<td>1.39 (0.98-1.98)</td>
<td>1.72 (1.22-2.41)</td>
<td>2.50 (1.83-3.40)</td>
</tr>
<tr>
<td>81/486 (16.7)</td>
<td>1.04 (1.03-1.05)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lower back, case/n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR (95% CI)</td>
<td>1 (Ref)</td>
<td></td>
</tr>
<tr>
<td>140/2059 (6.8)</td>
<td>40/510 (7.8)</td>
<td>46/462 (10.0)</td>
</tr>
<tr>
<td>1.29 (0.88-1.90)</td>
<td>1.83 (1.28-2.64)</td>
<td>2.76 (2.01-3.81)</td>
</tr>
<tr>
<td>83/489 (17.0)</td>
<td>1.04 (1.03-1.05)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Lower limb, case/n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PR (95% CI)</td>
<td>1 (Ref)</td>
<td></td>
</tr>
<tr>
<td>187/2044 (9.2)</td>
<td>128/506 (25.3)</td>
<td>99/456 (21.7)</td>
</tr>
<tr>
<td>2.19 (1.69-2.83)</td>
<td>1.99 (1.53-2.59)</td>
<td>2.86 (2.21-3.69)</td>
</tr>
<tr>
<td>124/485 (25.6)</td>
<td>1.04 (1.03-1.05)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Analysis of risk‡</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Activity range, h/wk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall pain, case/n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR (95% CI)</td>
<td>1 (Ref)</td>
<td></td>
</tr>
<tr>
<td>18/145 (12.4)</td>
<td>27/76 (35.5)</td>
<td>13/65 (20.0)</td>
</tr>
<tr>
<td>1.98 (1.20-3.26)</td>
<td>1.30 (0.78-2.16)</td>
<td>2.61 (1.67-4.09)</td>
</tr>
<tr>
<td>20/58 (34.5)</td>
<td>1.03 (1.02-1.05)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Case/n is the number of pain cases and the total number of records in each category from the available cases before imputation. Multiple records from an adolescent are possible in the serial cross-sectional analysis.

* Tertile categories were created among those reporting any sports activity separately for cross-sectional and for longitudinal analysis.

† Prevalence ratios and 95% CIs were estimated by Poisson regression adjusted for sex, age, body mass index, sleep length, screen time, and school. Of 2403 adolescents, 1277 had repeated measures (total 3680 records).

‡ Risk ratios and 95% CI were estimated by Poisson regression in which measures collected in 2008 were fitted to estimate risk of developing pain in 2009 in 374 adolescents who reported no musculoskeletal pain in 2008. Covariates included in the model were the same as for the cross-sectional analysis for PR, with the exception that school categories were included in the model as a determinant of covariance.

CI, confidence interval; PR, prevalence ratio; RR, risk ratio.
3.2. Longitudinal analyses

Longitudinal analyses also revealed a linear association between sports activity and new onset of pain. The RR (95% CI) of developing pain at any location at 1-year follow-up per 1 h/wk of sports time at baseline was 1.03 (1.02-1.05) ($P < 0.001$ for linear, $P = 0.92$ for quadratic; Table 2). The spline model also showed a linear association between sports activity and 1-year risk of pain (Figs. 2B and 3B). The test for nonlinearity was not significant ($P = 0.45$). The point estimate of the risk ratio reached 2.0 at 21.5 h/wk of sports activity, indicating the probability of developing pain doubled at that level of exposure.

All these results from multiple imputed analyses were similar to those from complete-case analyses. The variability of 10-time imputation, incorporated in the primary analyses, was <10% of total variance. Sensitivity cross-sectional analyses without students in the ninth or 12th grades, made using repeated measurements and single measurements, also yielded similar results. The PRs (95% CI) of pain per 1 h/wk of sports activity for both the repeated and the single measurement analyses were 1.03 (1.02-1.04).

4. Discussion

This study examined the dose–response relationship between organized sports activity and MSP among adolescents and found a linear association. Notably, a series of analyses rejected nonlinearity, and there was no inverse relationship (or protective effect) of sports activity on MSP. The more the participants played sports, the more likely they were to have and develop pain. Our results indicate that if an adolescent increases their sports activity by 1 h/wk, they have a 3% higher probability of developing pain 1 year later.

To our knowledge, our longitudinal analysis is the first of its kind to describe the dose–response relationship between sports activity and MSP through detailed analyses, including spline models. We confirmed that there was no U-shaped or plateaued trend for the positive association. A previous cross-sectional study of Canadian youth found that the dose–response relationship between physical activity and related injuries outside of school was a strong gradient relationship (linear in grades 6-8; quadratic in grades 9-10). Other studies have shown similar results from categorical analyses; British children who spent >360 min/wk playing sports had a higher risk of widespread pain than those who spent <100 min/wk (cross-sectional relative risk = 1.9; 1-year longitudinal relative risk = 2.0). In Finnish schoolchildren, vigorous exercise 5 to 7 times per week increased the risk of new-onset traumatic MSP at 1-year follow-up. However, some studies reported that physical activity reduced the risk of back pain. These differences may be partly due to methodological differences between the studies. For example, the study showing an inverse association used an accelerometer...
to assess overall physical activity in a small sample of 9-year-old children, whereas most other studies used self-reported measurements in older populations. Our study focused on organized sports activity, and overall physical activity was not measured; thus, our results are not directly comparable with those of studies examining overall physical activity. Legault et al. suggested that adolescent athletes had fewer symptoms affecting the spine than “typical adolescents” and similar prevalence of symptoms affecting the body’s extremities. However, their cross-sectional study had lower response rate (51.1% and 67.6% for the athlete adolescents and general adolescents, respectively) than those of other studies including ours, and the representativeness of the adolescent athlete population was questionable. Future meta-analysis of the literature might further clarify the relationship between physical activity and pain in school-aged youth.

We found that sports activity was associated with both traumatic and nontraumatic MSP. Both acute and chronic (overuse) injuries can be caused by excessive sports training, especially in skeletally immature adolescents. Some of these overuse injuries may have been captured by our questionnaire as nontraumatic pain. More than 80% of the pain in our study was reported as nontraumatic, which means there was no obvious event that acutely caused the symptoms. Its observed linear association with nontraumatic pain suggests a potential “silent killer” effect of prolonged sports activity. The interaction between sports activity and BMI was significant for upper but not for lower limb pain, which was contrary to our hypothesis that the combined effect of excess body weight and sports activity might be more harmful to the lower limb joints (because of a higher physical load) than to the joints of the upper limb. In a previous study, overweight was a risk factor for repeated forearm fractures. Poor gross motor ability, including balance, in the overweight population might explain the observed association.

Musculoskeletal pain prevalence (27.4%) in our study was within the range of the previous results, and lower back pain prevalence (9.2%) was consistent with a previous report in a Japanese population (9.7%). The high MSP prevalence, and its linear association with sports activity, suggests the need for preventive actions. To prevent overuse injuries, limiting the weekly and yearly participation time in sports is recommended by the American Medical Society for Sports Medicine. A systematic review showed that multi-intervention training programs (eg, balance training, structured warm-ups) effectively prevented sports injuries. These evidence-based prevention programs should be disseminated broadly and evaluated in implementation studies.

The American Academy of Pediatrics has highlighted the potential risks of sports specialization in young athletes. Most of the students in this study participated in only one sport. The benefits of participation in multiple sports should be examined in future prospective studies.

This study had several strengths. First, MSP was assessed by a questionnaire developed for school-based surveys in adolescents; this tool was confirmed to be reliable and valid in our study. Cause- and location-specific analyses of data obtained from the questionnaire provided in-depth information on the relationship between sports activity and pain. Second, the longitudinal analysis is a strength of this study, although it had a smaller sample size. Finally, this study recruited participants from all schools in the city, including students with elite athletic levels, and thus, our findings are generalizable to a general adolescent population rather than specifically applicable to limited elite athletes or clinically ill patients. Although the participants were recruited from a limited area in Japan, the average weekly time spent in sports activity (16.9 h/wk) was similar to that from a national survey of Japanese junior high school students (average physical activity time, excluding time in physical education class, among those participating in organized sports activity = 16.9 h/wk for male participants; 16.4 for female participants).

This study also had several limitations. First, despite the reliability assessment, self-reported sports activity may have been subject to recall bias. Other covariables were also self-reported, with unknown validity. Second, effects of unmeasured factors that may influence sports-MSP relationship, including puberty, smoking, mood of the adolescents, headache, tiredness, and socioeconomic status, could not be accounted for in this study. Third, the outcome of the longitudinal analysis was based on a single measurement at 1-year follow-up. Therefore, the risk of pain developing may have been underestimated because of undetected pain between questionnaire administrations. Finally, we did not examine the differences in the relationship between different durations or severities of pain and sports activity. Further study is needed to explore this.

In conclusion, sports activity had a clear linear association with MSP prevalence and risk among Japanese adolescents. The more the participants played sports, the more likely they were to have and develop pain. Each 1 h/wk of additional sports activity time was associated with a 3% higher probability of having or developing MSP. To optimize the safety and benefits of organized sports activity for adolescents, prevention of MSP should be an important consideration.

Conflict of interest statement

The authors have no conflicts of interest to declare.

This study was supported by a Grant-in-Aid from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan. M. Kamada is supported by a JSPS Postdoctoral Fellowship for Research Abroad. F. Imamura is supported by the Medical Research Council Epidemiology Unit (MC_UU_12015/1; MC_UU_12015/5). The funding bodies did not have a role in the study design, intervention, collection, analysis, or interpretation of data; writing the report; or the decision to submit the report for publication.

Acknowledgements

The authors deeply appreciate the cooperation of the staff members and all other people involved in this study.

Appendix A. Supplemental Digital Content

Supplemental Digital Content associated with this article can be found online at http://links.lww.com/PAIN/A247.

Article history:

Received 5 January 2016
Received in revised form 3 February 2016
Accepted 9 February 2016
Available online 27 February 2016

References


