Until it hurts? Epidemiology of musculoskeletal pain in youth sports

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Abstract Sports and physical activity provide multiple social and health benefits to participants, but may also increase the risk of developing musculoskeletal pain and injuries, especially in skeletally immature adolescents. This review outlines the 1) measurement and prevalence of musculoskeletal pain in adolescents, 2) dose-response relationship between the organized sports activity and musculoskeletal pain, 3) high risk population, based on our previously published epidemiological studies in Japan, and finally, 4) prevention strategy and its evaluation.

In our school-based cohort study in Unnan, Shimane, a total of 2403 adolescents aged 12 to 18 years responded to two serial surveys, conducted 1 year apart. The prevalence of overall pain was 27.4% (lower limbs: 15.4%, upper limbs: 9.5%, and lower back: 8.5%). Sports activity had a clear linear association with musculoskeletal pain prevalence and risk. The more the adolescents played sports, the more likely they were to have pain or develop pain. Each 1 hour/week of additional sports activity time was associated with a 3% higher probability of having or developing pain. Some population groups were at higher risk of musculoskeletal pain, such as overweight adolescents and regular players with fewer teammates. To optimize the safety and benefits of organized sports activity for adolescents, prevention of musculoskeletal pain should be an important consideration. More observational and intervention studies with quality designs and development of a national surveillance system for (youth) acute and chronic sports injuries are needed in Japan.

Keywords: epidemiology, exercise, low back pain, cumulative trauma disorders, injuries

Introduction

Physical activity, including organized sports, has multiple social and health benefits for children and adolescents1-3). However, participation in sports may involve intense physical demands and thus result in a higher risk of musculoskeletal pain. Musculoskeletal pain is a common health problem among adolescents, with a prevalence ranging from 4 to 40%4). In school-aged youth, musculoskeletal pain is associated with not only functional disability5) and lower quality of life6), but also future risk of musculoskeletal pain during adulthood7).

This review outlines the 1) measurement and prevalence of musculoskeletal pain in adolescents, 2) dose-response relationship between sports activity and musculoskeletal pain, 3) high risk population, based on our previously published epidemiological studies in Japan8,9), and finally, 4) prevention strategy and its evaluation.

Measurement and prevalence of musculoskeletal pain

First, to identify the size of the problem, i.e., prevalence of musculoskeletal pain, we developed a questionnaire for school-based surveys (Fig. 1)10). Pain locations included the neck, upper limbs, chest, upper back, lower back, buttocks, and lower limbs. Students were considered to suffer from musculoskeletal pain, if pain was present recently at least several times a week in at least one part of the body. Additionally, we differentiated types of pain by cause (traumatic or non-traumatic) based on the students’ questionnaire responses. Both test-retest reliability (Cohen’s kappa = 0.67) and criterion validity with a face-to-face interview with health professionals trained by an experienced orthopedist (Cohen’s kappa = 0.52) were acceptable. The English version of the questionnaire is available elsewhere11) and original Japanese version is available upon request from the corresponding author (MK).

In October 2008 and October 2009, a total of 2403 adolescents, aged 12 to 18 years in Unnan City, Shimane,
Questions about pain

For each part of your body, please answer about “pain” that you have felt recently. If you do not have any pain, please circle “no pain”.

(Example)

9. (Location) < have pain > no pain → Proceed to 2. Upper limb

1. Neck < have pain · no pain → Proceed to 2. Upper limb

2. Upper limb (shoulder, arms, hands) < have pain · no pain → Proceed to 3. Chest

3. Chest < have pain · no pain → Proceed to 4. Upper back

4. Upper back < have pain · no pain → Proceed to 5. Lower back

5. Lower back < have pain · no pain → Proceed to 6. Buttocks

6. Buttocks < have pain · no pain → Proceed to 7. Lower limbs

7. Lower limbs (thigh, hip, knee, foot, etc.) < have pain · no pain

1. Neck

(1) Is it because you were injured (e.g., fell, hit a person or an object)?

(2) How long have you had the pain?

(3) How often do you feel the pain?

2. Upper limb (shoulder, arms, hands)

(1) Is it because you were injured (e.g., fell, hit a person or an object)?

(2) How long have you had the pain?

(3) How often do you feel the pain?

3. Chest

(1) Is it because you were injured (e.g., fell, hit a person or an object)?

(2) How long have you had the pain?

(3) How often do you feel the pain?

4. Upper back (shoulder, back, neck)

(1) Is it because you were injured (e.g., fell, hit a person or an object)?

(2) How long have you had the pain?

(3) How often do you feel the pain?

5. Lower back (back, lower back)

(1) Is it because you were injured (e.g., fell, hit a person or an object)?

(2) How long have you had the pain?

(3) How often do you feel the pain?

6. Buttocks (buttocks, lower legs)

(1) Is it because you were injured (e.g., fell, hit a person or an object)?

(2) How long have you had the pain?

(3) How often do you feel the pain?

7. Lower limbs (thigh, hip, knee, foot, etc.)

(1) Is it because you were injured (e.g., fell, hit a person or an object)?

(2) How long have you had the pain?

(3) How often do you feel the pain?

(4) At which location do you have the pain?

Fig. 1 Pain questionnaire (Reproduced with permission from Kamada et al. 2016 Pain)
responded to two school-based serial surveys, conducted 1 year apart (response rate 79% and 86%, respectively). Self-administered questionnaires were distributed to all of the students in all of 7 junior-high and 3 high schools in Unnan City and returned through the schools. Responses from students who received special needs education and questionnaires with invalid responses were excluded.

Among the 27.4% of the students who had musculoskeletal pain, non-traumatic pain was more prevalent (22.3%) than traumatic pain (5.8%). Fig. 2 illustrates the prevalence of pain by location. The lower limbs were the most commonly affected (15.4%), followed by the upper limbs (9.5%), and the lower back (8.5%). The overall prevalence (27.4%) in our study was within the range of previous reports4), and lower back pain prevalence was similar to that in a previous report in a Japanese population aged 9-15 years in Niigata City (9.7%)10).

Dose-response relationship between sports activity and pain

Previous studies have reported inconsistent findings on the relationship between physical activity and pain11). Some studies reported that, physical activity increases the risk of lower back12), lower limb13,14), traumatic15), overall musculoskeletal pain16), and widespread pain17), whereas others reported the opposite, suggesting that physical activity reduces the risk of back pain18,19). Additionally, whether or not a non-linear dose-response relationship exists was uncertain. There may be a U-shaped curve, i.e., both too little and too much physical activity may increase the risk of musculoskeletal pain20). To optimize the safety and benefits of physical activity and organized sports for adolescents, understanding the shape of the dose-response curve is important. Thus, we examined the dose-response relationship between organized sports activity and musculoskeletal pain in adolescents9).

In the aforementioned school-based survey, we carried out cross-sectional and longitudinal analyses of the data collected. Organized sports activity was defined as sports activities that took place after school programs on weekdays and/or weekends (i.e., bukatsudou) or activities that were organized by sports clubs. The test-retest reliability of the weekly organized sports time question was acceptable (intraclass correlation coefficient = 0.85).

The mean (SD) time spent in organized sports activity was 16.9 (5.7) hours/week for the 1067 (45.3%) students who participated in organized sports. This number was similar to that from a national survey of Japanese junior high school students (16.9 hours/week for male; 16.4 for female)21). In our study, the upper 5% of participants spent ≥27.0 (95th percentile) hours/week in sports activity. Cross-sectional analysis showed that sports activity and pain prevalence had a significant linear association; students who spent the longest time in sports activity (≥18.5 hours/week) experienced a two-fold greater rate of pain than students who did not participate in organized sports after adjustment for potential confounders. The test for linearity was significant (P < 0.001); additional 1 hour/week of sports activity was associated with a 3% higher probability of having pain (prevalence ratio, 95% confidence interval [CI] = 1.03, 1.02-1.04). Similarly significant linear associations were found in the cause- and location-specific analyses and subgroup analyses by sports types. A cubic spline model22) also showed a linear association between sports activity and pain prevalence.
(Fig. 3A); 40% of students were predicted to have pain, when they played sports for 21.8 hours/week.

Longitudinal analysis also revealed a linear association between sports activity and new onset of pain. The risk ratio (95% CI) of developing pain at any location at 1-year follow-up per 1 hour/week of sports time at baseline was 1.03 (1.02-1.05) ($P < 0.001$ for linear). The spline model also showed a linear association between sports activity and 1-year risk of pain (Fig. 3B). The point estimate of the risk ratio reached 2.0 at 21.5 hours/week of sports activity, indicating that the probability of developing pain doubled at that level of exposure.

These cross-sectional and longitudinal analyses showed that, the more the adolescents played sports, the more likely they were to have or to develop pain. Notably, a series of analyses rejected non-linearity and there was no inverse relationship (or protective effect) between sports activity and musculoskeletal pain. Both acute and chronic (overuse) injuries can be caused by excessive sports training, especially in skeletally immature adolescents. More than 80% of the pain in our study was reported as non-traumatic, which means there was no obvious event that acutely caused the symptoms. The observed linear association with non-traumatic pain suggests a potential "silent killer" effect of prolonged sports activity. Our study focused on organized sports activity, and overall physical activity was not measured. Future longitudinal study and meta-analysis of the literature might further clarify the relationship between overall physical activity and pain in adolescents.

**High risk population**

**Overweight.** To identify a high risk population, we also assessed whether excess sports activity was particularly associated with musculoskeletal pain among students with high body mass index (BMI). Overweight adolescents may experience greater impacts of physical activity on musculoskeletal pain than lean adolescents. In our study, 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 for pain at other locations ($P > 0.5$). In the further stratified analysis, the prevalence ratios for upper limb pain were higher across the sports activity levels among participants with higher BMIs (Fig. 4). These results were 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 limbs. In a previous study, overweight was considered to be a risk factor for repeated forearm fractures. Poor gross motor ability, including balance, in the overweight population might explain the observed association.

**Playing and team status.** In addition, we examined the association of playing status (regular or non-regular players) and team status (fewer or more teammates) with pain. Regular players with limited numbers of teammates may have a heavier physical burden because of a longer duration of playing time compared with non-regular players with a sufficient number of teammates. For 632 team sports players, the teammate quantity index (TQI) was calculated as follows:

$$TQI = \frac{\text{number of teammates in a given grade}}{\text{required number of players for the sport}}$$

The required number of players for each sport was assigned as follows: Baseball and Softball = 9; Basketball

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**Fig. 3** Pain prevalence ratio and risk ratio of having pain at 1-year follow-up by time spent in sports activity. The solid lines present the adjusted prevalence ratio (A, $n = 2403$) and risk ratio (B, $n = 374$) derived from spline regression models. The dashed lines show the 95% confidence intervals. (Reproduced with permission from Kamada et al. 2016 *Pain*)
Musculoskeletal pain in youth sports

In Japan, the average number of members in sports teams varies by sport: Baseball = 5; Soccer = 11; and Volleyball = 6. For example, in the situation of a baseball team with 14 students in the second grade, the TQI for these second grade students is 14 divided by 9 (i.e., TQI = 1.6). A higher TQI indicates more teammates in the same grade in their team with consideration for each sport. TQI was dichotomized as high or low, using median value (1.3) as the cutoff.

When grouped according to playing status or team status, 140 (47.0%) regular and 130 (41.7%) non-regular players had musculoskeletal pain, whereas 142 (47.0%) players with fewer teammates (lower TQI) and 127 (41.8%) players with more teammates (higher TQI) had musculoskeletal pain. In the multivariable analysis, regular players with fewer teammates (lower TQI) had a higher prevalence of low back pain compared with non-regular players with more teammates (higher TQI) (21.3% vs 8.3%; adjusted prevalence ratio = 2.08 [1.07-4.02], Fig. 5). Although the associations with overall pain and other locations were not significant, the prevalence of pain was highest in regular players with lower TQI for all pain outcomes.

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clubs for elementary school children decreased from 26.7 members per club in 2002 to 21.8 in 2014\textsuperscript{29}. A decrease in the number of youth sports players may further contribute to increased physical burden, and thus to an increase in risk of pain among the remaining players on the team. Preventive actions focusing on youth sports players with small numbers of teammates may be necessary and will require multidisciplinary cooperation of stakeholders such as coaches, parents, and sports policy makers.

Prevention Strategy and Evaluation

The American Academy of Pediatrics has highlighted the potential risks of sports specialization in young athletes\textsuperscript{23}. Most of the students in our study participated in only one sport\textsuperscript{8}. The benefits of participation in multiple sports should be examined in future prospective studies\textsuperscript{30}. In addition, to prevent overuse injuries, limiting the weekly and yearly participation time in sports is recommended by the American Medical Society for Sports Medicine\textsuperscript{31}. A systematic review showed that multi-intervention training programs (e.g., balance training, structured warm-ups) effectively prevented sports injuries\textsuperscript{32}). These evidence-based prevention programs should be disseminated broadly and evaluated in implementation studies\textsuperscript{33}).

More research, such as observational studies to detect risk factors and intervention studies to examine prevention strategies with the measurement of sports injuries or musculoskeletal pain as an outcome is needed in Japan. The relevant reporting guidelines, e.g., STROBE\textsuperscript{34}) for observational studies, CONSORT for randomized trials (standard checklist\textsuperscript{35}), cluster randomized trial extension\textsuperscript{36}, and/or non pharmacologic treatment extension\textsuperscript{37}), and RE-AIM\textsuperscript{38} or PAIREM\textsuperscript{39}) for implementation studies, should be checked earlier, to minimize the risk of bias in the studies. The commitment of epidemiologists and statisticians to such studies is strongly recommended. Since there is no national surveillance system for (youth) sports injuries that includes both acute and chronic injuries in Japan, development of such a system is necessary to check the trend and evaluate the effect of all of preventive efforts collectively on a national scale.

Conclusion

Musculoskeletal pain is a common health problem among adolescents, with a prevalence of 27.4\% in our study conducted in Japan. Sports activity had a clear linear association with musculoskeletal pain prevalence and risk. The more the adolescents played sports, the more likely they were to have and develop pain. Each 1 hour/week of additional sports activity time was associated with a 3\% higher probability of having or developing pain. Some population groups were at higher risk of musculoskeletal pain, such as overweight adolescents and regular players with fewer teammates. To optimize the safety and benefits of organized sports activity for adolescents, prevention of musculoskeletal pain should be an important consideration. More observational and intervention studies with quality design as well as the development of a national surveillance system for (youth) acute and chronic sports injuries in Japan are needed.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

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References

38) Glasgow RE, Vogt TM and Boles SM. 1999. Evaluating the public health impact of health promotion interventions: the...

39) Shigematsu R, Kamada M, Okada S, Sato A, Okura T, Naka-
agaichi M, Kitayuguchi J and Suzuki R. 2016. A tool to as-
sess population approaches that promote physical activity - A
modified RE-AIM Model: PAIREM -. *Res Exerc Epidemiol*