


BMJ Open Orthopaedic medical examination for young amateur athletes: a repeated cross-sectional study from 2014 to 2018

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ABSTRACT

Objectives Medical examinations for adult elite athletes are performed all over the world, however, no studies in the relevant English literature have reported on orthopaedic medical examinations for young amateur athletes. The purpose of this study was to report the results of orthopaedic medical examinations of the spine and lower extremities in young amateur athletes.

Methods This repeated cross-sectional study from 2014 to 2018 included a total of 323 young amateur athletes (age, 12–18 years) who were active in one of the following four sports: boxing, canoeing, weightlifting and track and field. The orthopaedic medical examination consisted of six assessments (physical examinations, the generalised joint laxity, muscle and joint tightness, static alignment and muscle volume of the lower extremities and the medial longitudinal arch of the foot). Questions regarding pain in the spine and lower extremities were also performed.

Results Among 323 young amateur athletes, 17 (5.3%) had received orthopaedic treatment at the time of the medical examination, with spondylolysis being the most common cause (29.4%, 5/17). Among 306 young athletes who had not received orthopaedic treatment, 61 (19.9%) had at least one positive finding in physical examinations or had pain in the spine or lower extremities. Anterior drawer test of the ankle and Kemp test for the spine accounted for 34% and 28% of positive findings, respectively. Low back pain and knee pain accounted for 58% and 16% of pain, respectively.

Conclusions The present study showed that approximately one-fifth of young amateur athletes who had not received orthopaedic treatment had pain in the spine and lower extremities and positive findings in physical examinations that may require orthopaedic treatments. In addition to the early detection of injuries, orthopaedic medical examinations for young amateur athletes provide an opportunity to educate such athletes.

INTRODUCTION

The number of school-aged children (age, 5–18 years) who participate in sports has been increasing and is estimated to be approximately 40 million in the USA.^{1 2} These young athletes will sustain about 4 million sport-related injuries annually and will require 2.6 million emergency department visits.^{2–4} Pain affecting the low back or lower

Strengths and limitations of this study

- This study presents the results of orthopaedic medical examinations for 323 young amateur athletes.
- The orthopaedic medical examination in this study was originally developed in our country.
- The examination consists of six categories (physical examinations of the spine and lower extremities, generalised joint laxity, muscle and joint tightness, static alignment, muscle volume of the lower extremities and medial longitudinal arch of the foot).
- This study evaluated four sports activities (boxing, canoeing, weightlifting and track and field), which makes it impossible to describe the results of young athletes who participate in other sports activities.
- It remains unclear whether the procedures or frequency of the orthopaedic medical examinations in this study are valid because of no previous studies reporting orthopaedic medical examinations for young amateur athletes.

extremities is a common report among young athletes. The incidence of low back pain (LBP) among young athletes has been reported in several articles,^{5–7} and Micheli and Wood reported that 47% of young athletes with LBP had spondylolysis.⁸ It has also been reported that LBP is more prevalent in sports requiring high spinal loads.^{9–11} Several studies have reported that the foot morphology, such as low and high arch, made the athlete's foot more prone to injury.^{12 13} Excessive foot pronation has been identified as a risk factor for injuries in football and in the development of medial tibial stress syndrome.^{14 15} The knee is the most frequently injured joint in young athletes.¹⁶ Kujala *et al* reported that the incidence of knee injuries was 20.8% in soccer players and 13.1% in runners.¹⁷ Hall *et al* found that early sport specialisation in female adolescents increased the relative risk of anterior knee pain, Osgood Schlatter disease and Sliding Larsen Johansson disease in comparison to multiple sports activities.¹⁸

According to the International Olympic Committee consensus statement on young athletic development, it is documented that designing youth athlete development programmes to mitigate the risk of overuse injuries, performing evidence-based injury prevention programmes and developing knowledge translation strategies that will promote health in young athletes are recommended.¹⁹ In order to protect young athletes from acute and overuse injuries, multidirectional approaches are required. For example, many researchers have demonstrated the efficacy of prevention programmes such as neuromuscular training for anterior cruciate ligament (ACL) injury.^{20–22} In addition to prevention programmes, early detection of these reports and symptoms is extremely important for enabling treatments to be initiated as early as possible and to allow young athletes to return to their respective sports without severe complications. The orthopaedic medical examination (orthopaedic screening) for young athletes may be valuable, not only for the early detection of injuries in young athletes but also for evaluating physical characteristics and educating athletes, their parents and coaches. It is important to identify individuals who have some injuries and disorders, but who have not taken orthopaedic treatments. There is a lack of evidence regarding how many young athletes—with injuries or conditions that should be managed by orthopaedic treatments—keep participating in their sports activities. In the majority of countries, medical examinations are usually performed for elite adult athletes and are not performed for young athletes, especially for amateur athletes. To the best of our knowledge, no studies in the relevant English literature have reported on orthopaedic medical examinations for the screening of young amateur athletes. The purpose of the present study was to report the results of orthopaedic medical examinations for young amateur athletes.

MATERIALS AND METHODS

Patient and public involvement

Patients or the public were not involved in the design of the study.

Study design

The orthopaedic medical examinations were annually performed in a single institute from 2014 to 2018. Informed assent and consent were obtained from the participants and their parents before the enrolment of this study.

Participants

All the study population included young athletes (junior high school or high school students) who were selected in the study area for the annual national championship tournament in Japan. Among these young athletes, young athletes who participated in one of four sports activities; boxing, canoeing, weightlifting and track and field, were included in this study. The included sports activities were

determined after a discussion with the sports association in the study area, due to the limited cost and number of available medical staff. The mean duration of practising each sport was 5.0 years (range, 4–6 years). The mean frequency and duration of each practice/week were 5.3 times (range, 5–6 times) and 3.8 hours (range, 3–4 hours), respectively.

Procedures

All of the enrolled athletes were assessed without information regarding previous and present injuries or symptoms affecting the spine and lower extremities. The participants were questioned as to whether they had seen an orthopaedic doctor within the last 4 weeks and whether they had pain and symptoms in the spine and lower extremities at the time of medical examinations. The pain and symptoms that had lasted for more than 4 weeks were considered.

Orthopaedic medical examinations were performed for all of the included individuals by a total of 10 senior orthopaedic surgeons and 20 physical therapists who were specialised in sports medicine. In order to assess the individuals in a reliable and reproducible manner, the details of all examinations were documented before the initiation of this study. All medical providers performed medical examinations based on these reports throughout the study. The orthopaedic medical examination in this study was divided into six categories (table 1): category 1, physical examinations of the spine, knee and ankle joints; category 2, assessment of the generalised joint laxity (GJL); category 3, assessment of the muscle and joint tightness of the lower extremities; category 4, assessment of the static alignment of the lower extremities; category 5, assessment of the muscle volume of the lower extremities; category 6, assessment of the height of the medial longitudinal arch of the foot. Category 1 was performed by orthopaedic surgeons, and other categories (categories 2–6) were performed by physical therapists. The procedures of orthopaedic medical examinations were introduced by Nakajima²³ and were modified by the authors in this study.

Category 1

Physical examinations included Kemp test for spine injuries (figure 1),²⁴ six assessments for knee injuries (lateral stress test of the patella, Lachman test, posterior drawer test, McMurray test, varus and valgus stress test) and two assessments for ankle injuries (anterior drawer test and inversion stress test). When the young athlete reported of some pain or disorders that could not be assessed by the above physical examinations, additional physical examinations were performed to evaluate them.

Category 2

The Japanese assessment method for the GJL, which was introduced by Simon *et al*¹⁶ and which is commonly used to evaluate GJL in Japan, was used in the present study because other methods for the assessment of GJL,

Table 1 Summary of the orthopaedic medical examinations in this study

Assessment (six categories)	Methods
1. Physical examinations	
Spine	Kemp test
Knee joint	Lateral stress test of the patella
	Lachman test
	Posterior drawer test
	McMurray test
	Varus stress test
Ankle joint	Valgus stress test
	Anterior drawer test
	Inversion stress test
2. Generalised joint laxity	Nakajima criteria
3. Muscle and joint tightness of the lower extremities	Finger floor distance
	Passive straight leg raising test
	Thomas test
	Ely's test
4. Static alignment of the lower extremities	Dorsiflexion of the ankle joint
	Quadriceps (Q) angle
	Leg-heel angle
5. Muscle volume of the lower extremities	Circumferential length of the thigh
	Circumferential length of the calf
6. The height of medial longitudinal arch of the foot	The height from the tip of the navicular bone to the ground surface

including Beighton criteria,²⁵ cannot evaluate the spine, hip and ankle joints. This assessment method evaluates six bilateral joints (shoulder, elbow, wrist, hip, knee and ankle joint) and the spine (figure 2). When one of the 12 joints meets the criteria, a score of 0.5 points is given; when the spine meets the criteria, a score of 1.0 point is given. Total scores range from 0 to 7 points, with a higher score indicating the presence of GJL.

Category 3

Muscle and joint tightness of the lower extremities was assessed by finger floor distance,²⁶ straight leg raising (SLR) test,²⁷ Thomas test²⁸ and Ely's test²⁹ and assessment of the active dorsiflexion of the ankle joint in the supine position with a goniometer (figure 3).

Category 4

The quadriceps angle (Q angle) was examined in the supine position with a goniometer to measure the line connecting the anterior superior iliac spine and the midpoint of patella intersecting with the line connecting the tibial tubercle to the midpoint of the patella.³⁰ The leg-heel angle was evaluated from behind the individual in a standing position and was classified as supination, neutral and pronation.

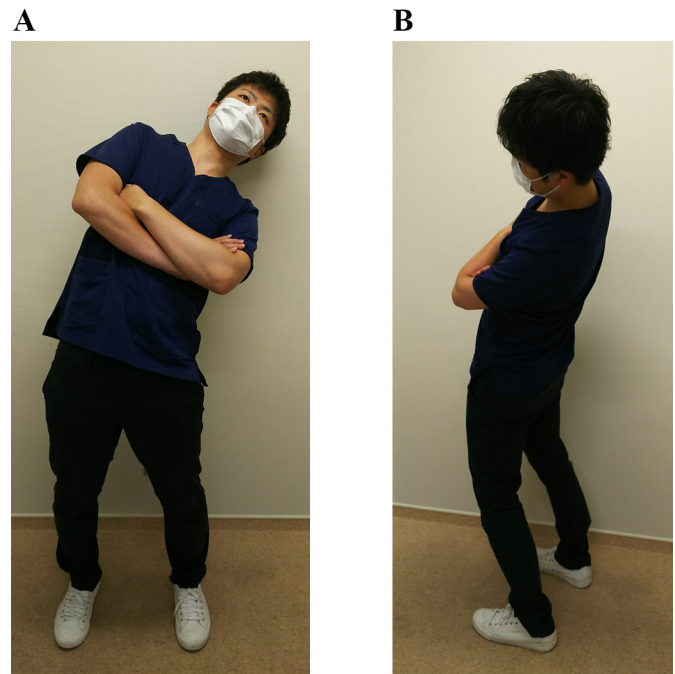


Figure 1 Left-sided Kemp test. (A) Front view and (B) lateral view. Lateral flexion and extension of the trunk is performed with the subject standing in a bipedal stance. The test is positive when the low back pain is present. This test is performed on both sides.

Category 5

The muscle volume of the lower extremities was assessed with the subject standing in a relaxed bipedal stance, by the circumferential length of the thigh at 10 cm above the proximal tip of the patella and by the maximum circumferential length of the calf.

Category 6

The medial longitudinal arch of the foot was assessed by the height from the tip of the navicular tubercle to the ground surface with the subject standing in a relaxed bipedal stance.³¹ The tip of the navicular tuberosity was palpated and marked with a marking pen. A ruler was used to measure the height of the navicular tuberosity from the ground (figure 4). Low arch was defined as a height shorter than 15 mm in this study because Roth *et al* reported that the height of the navicular bone from the floor was in proportion with that of the longitudinal arch of the foot, and the mean navicular height in patients with flexible flat foot was 15.67±4.3 mm.³²

Statistical analysis

All data collected in this study were recorded and analysed using SPSS software (V.21.0, SPSS, Chicago, Illinois, USA). Descriptive statistics was reported as percentage or mean±SD. All examinations resulted were stratified by sport.

RESULTS

A total of 323 young athletes (age, 12–18 years) were included in the present study. The mean age was 15.9±1.1 years, and 218 athletes were men (67.5%). The

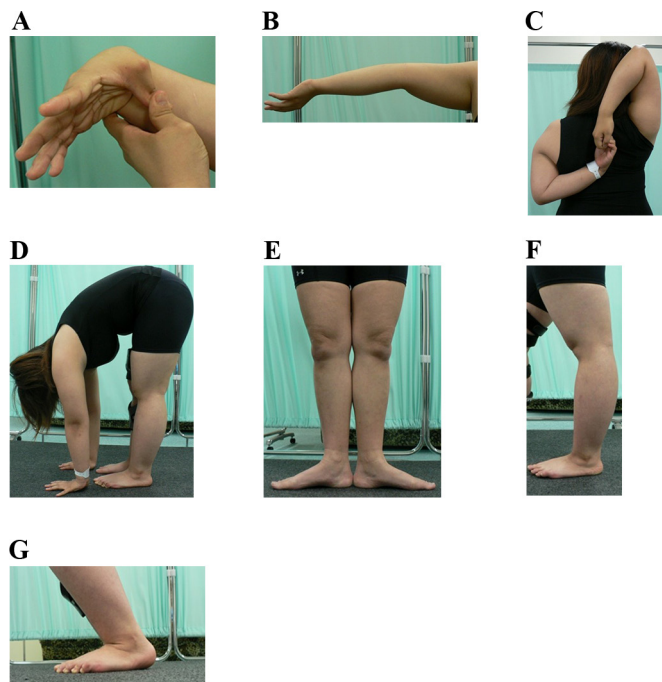


Figure 2 The Nakajima criteria for generalised joint laxity. (A) Passive opposition of both thumbs to volar aspects of ipsilateral forearms. (B) Hyperextension of both elbows beyond 15°. (C) Crossing fingers behind the back. (D) Forward flexion of the trunk with the knees fully extended and palms resting on the floor. (E) External rotation of both hips beyond 90°. (F) Hyperextension of both knees beyond 10°. (G) Dorsiflexion of both ankles beyond 45°. Tests other than (C) and (D) are bilateral. The patient receives a score for each individual joint that is determined based on the evaluation of these items (score 0–7).

participants included 110 boxers (men/women, 97/13), 67 canoeists (men/women, 45/22), 61 weightlifters (men/women, 40/21) and 85 track and field players (men/women, 36/49). The characteristics of the young athletes are summarised in [table 2](#).

Young athletes who had received orthopaedic treatment

Among 323 young athletes, 17 (5.3%) had received an orthopaedic treatment at the time of the orthopaedic medical examination; the details are summarised in [figure 5](#). The percentage of individuals in the weightlifting, track and field, boxing and canoeing groups who had required orthopaedic treatments was 9.8% (6/61), 7.1% (6/85), 3.6% (4/110) and 1.5% (1/67), respectively. Spinal and lower extremity pathologies were the reason for orthopaedic treatment in 35.3% (6/17) and 41.2% (7/17) of the cases, respectively. Spondylolysis was the most common reason for seeking orthopaedic treatment (5/17, 29.4%), followed by recurrent ankle sprain (2/17, 11.8%).

The prevalence of pain and results of category 1

The prevalence of pain in the spine and lower extremities and the results of the physical examinations (excluding the 17 athletes who had received orthopaedic treatment at the time of medical examination) are summarised in

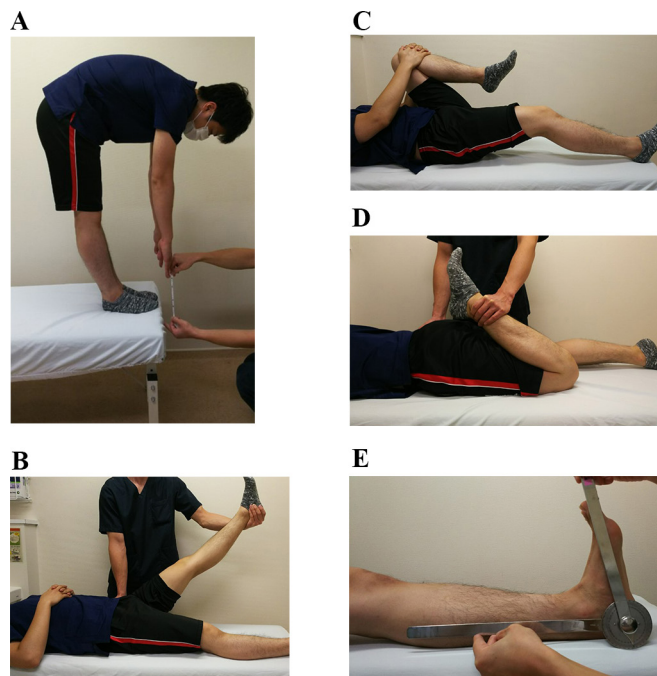


Figure 3 The assessment of muscle and joint tightness of the lower extremities. (A) Finger floor distance. The test is performed with the subject standing straight, feet together. The subject is instructed to bend forward as far as possible, with their knees, arms and fingers fully extended. The vertical distance between the tip of the middle finger and the floor is measured with a ruler. In the present study, the test was positive when the middle finger did not touch the floor. (B) Straight leg raising test. The patient's leg is lifted by the posterior ankle, while maintaining the knee joint fully extended, until the subject complains of pain or tightness in the back of the leg. (C) Thomas test. The test is performed with the subject in the supine position. The ipsilateral limb is gradually flexed to eliminate lumbar lordosis. When flexion of the contralateral hip is present, the test is positive. (D) Ely's test. The ipsilateral knee joint is gradually flexed with the subject in the prone position. The test is positive when the patient's hip flexes up from the floor. (E) Assessment of the dorsiflexion of the ankle joint. The evaluation was performed with the subject in the supine position using a goniometer.

[figure 6](#). Among 306 young athletes, 61 (19.9%) had pain in the spine and/or the lower extremities or had positive findings in the physical examinations. Of 50 (16.3%) had at least one positive findings of physical examinations and 50 (16.3%) had spinal and/or lower extremity pain. The percentage of individuals in weightlifting, track and field, canoeing and boxing was 32.7% (18/55), 30.4% (24/79), 16.7% (11/66) and 7.5% (8/106), respectively. The origin of pain was the low back in 29 (58%), followed by the knee in 8 (16%) and the ankle in 5 (10%). Among 50 who had positive findings in physical examinations, 17 (34%) had positive findings in anterior drawer test of the ankle, 14 (28%) had in Kemp test, 11 (22%) had in inversion stress test of the ankle and 4 (8%) had in McMurray test.



Figure 4 Photograph showing the measurement of the medial longitudinal arch of the foot. The height from the tip of the navicular tubercle to the ground surface was measured with a ruler, and defined as low arch when it was <15 mm.

The results of categories 2–6

The results of categories 2–6 are shown in [table 3](#).

DISCUSSION

The present study demonstrated that almost a fifth (19.9%) of young athletes, who had not previously been treated by orthopaedic doctors, had spinal and/or lower extremity pain and/or had positive findings in physical examinations of the spine and lower extremities that may need a management by orthopaedic doctors. Medical check-ups are generally performed for elite adult athletes in most countries,^{33 34} and many studies have reported on cardiac screening with electrocardiography.^{35 36} Cardiac screening has been recommended as preparticipation examination for both top athletes and amateur athletes to identify fatal cardiac pathologies.³⁷ A number of studies have reported the epidemiology of the incidence of pain and risk factors for some sports-related injuries

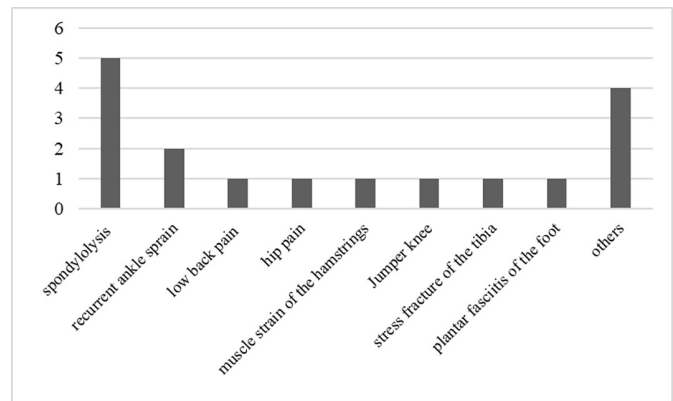


Figure 5 The reasons why young athletes who had received orthopaedic treatments at the time of the medical examination (n=17).

in young amateur athletes.^{38–40} However, to the best of our knowledge, no studies in the relevant English literature have reported on the implementation of orthopaedic medical examinations (orthopaedic screening) for young amateur athletes. Participating in sports activities lead to health promotion in young generations, including a positive body image, a better cardiorespiratory function and an improved sense of well-being.^{41 42} However, most participants, their parents and coaches tend to seek improved skills and victory in competitions, which requires overtraining and which has the potential to cause both acute and chronic injuries. In addition to physiological overtraining, young athletes are increasingly exposed to psychological overload from excessive and unrealistic expectations by their parents/coaches,⁴³ which may result in a risk of concealing pain and symptoms. In order to detect and treat young athletes with any injury or disease as soon as possible, orthopaedic medical examinations may be an effective intervention. It has been recommended that intense training in a single sport should be delayed until late adolescence to

Table 2 Characteristics of young athletes

(A) Male athletes				
Variable	Boxers (n=97)	Canoeists (n=45)	Weightlifters (n=40)	Track and field athletes (n=36)
Age, years	15.8±1.5	15.9±0.7	16.1±0.8	16.2±0.8
Height, cm	165.3±9.1	169.5±5.1	166.5±5.7	175.2±6.5
Weight, kg	53.9±9.4	62.3±6.7	70.3±11.7	72.5±17.8
BMI	19.6±1.8	21.7±2.1	25.3±4.6	23.6±5.0
(B) Female athletes				
Variable	Boxers (n=13)	Canoeists (n=22)	Weightlifters (n=21)	Track and field athletes (n=49)
Age, years	15.9±1.5	16.1±0.7	16.3±0.8	16.1±0.9
Height, cm	154.3±4.6	155.5±5.0	154.9±3.9	162±4.6
Weight, kg	47.8±5.3	53.5±6.1	57.6±9.2	55.0±8.4
BMI	19.3±3.2	22.1±1.9	23.9±3.0	21.0±3.1

Data presented as mean±SD unless otherwise indicated.
BMI, body mass index.

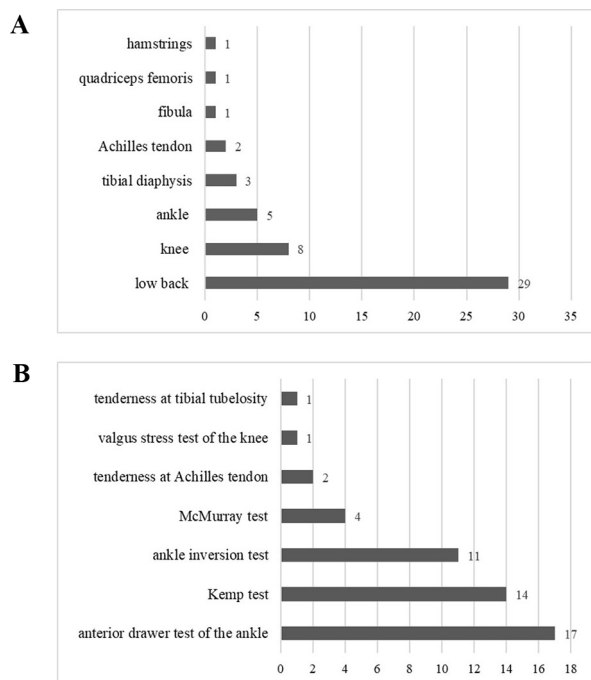


Figure 6 (A) Details of pain identified at the orthopaedic medical examination for young athletes (n=50). (B) Details of positive findings of physical examinations for young athletes (n=50).

minimise the risk of injury and psychological stress.^{44 45} However, youth sports specialisation in a single sport at the exclusion of other sports has been increasing,⁴⁶ as the participants in the present study did. Several injury prevention programmes are demonstrated to reduce the incidence of sports-specific injuries,^{20–22 47} however, there is a lack of knowledge and corresponding behaviour among young athletes and their coaches with regards to these prevention strategies. After collecting and analysing the data of the medical examinations, we informed the young athletes and their patients/coaches of the results of the examinations to educate them and their parents. We believe that education after medical examinations will contribute to reducing the prevalence of joint-related pain and injuries in high-risk athlete who participate in a single sport. However, there are many issues that remain undecided in orthopaedic medical examinations for young athletes, including what kinds of assessments should be performed, the timing (off-season vs in-season) and frequency of the medical examinations, the level of young athletes who should undergo examinations and cost problems. No studies or protocols have answered these issues. Further study is needed to clarify these problems and to improve the quality of orthopaedic medical examinations.

The present study showed that spondylolysis (29.3%) and recurrent ankle sprains (11.8%) were the main reasons for young athletes to receive orthopaedic treatments. LBP accounted for 58% of the origins of the pain, and the anterior drawer test and Kemp test accounted for 62% of positive findings in physical examinations. It was

reported that 7% of 12-year olds and 53% of 18-year olds had experienced at least one episode of LBP in their lifetime.⁴⁸ LBP is a particularly common symptom in competitive young athletes, with an estimated prevalence ranging from 1% to 30%.^{49 50} Spondylolysis is a major cause of LBP in young athletes,^{8 51} and Sakai *et al* reported that the bony healing rate after conservative treatment of spondylolysis in patients with early stage was 100%, while it was 80% in patients with the progressive stage.⁵² Orthopaedic medical examinations would enable physicians to detect young athletes with spondylolysis at an early stage, which may lead to favourable clinical outcomes after conservative treatment without residual complications. Acute ankle sprain has been reported to be the most common injury sustained by athletes, accounting for almost 40% of sports injuries.^{53 54} If acute ankle sprains are not treated appropriately, 10%–20% lead to recurrent ankle sprains and chronic ankle instability.⁵⁵ Recurrent ankle sprains are also prevalent in young athletes.^{56 57} Previous studies reported that less than 64% of athletes did not seek medical treatment after an ankle sprain,^{58 59} indicating ignorance and a lack of knowledge in relation to ankle sprain. Orthopaedic medical examinations will help to detect young athletes with recurrent ankle sprains and to instruct them to see an orthopaedic physician. This would lead to a reduction in the prevalence of chronic lateral ankle instability in young athletes.

Another interesting point of the present study was that orthopaedic medical examinations could evaluate physical characteristics and the pattern of injuries and symptoms in each sport. Due to the results of the present study, participants showed specific findings depending on the type of sport. Educating young athletes and their coaches about these characteristic findings in each sport would be a preventive strategy for sports-related injuries. Weightlifters tended to have relatively tight quadriceps and hamstrings in comparison to athletes in other sports activities, as was shown in the results of the Ely's test and the SLR test. Several studies described that LBP was most common in weightlifters.^{34 60} Tight quadriceps and hamstrings are considered risk factors for LBP,^{61 62} therefore weightlifters should be educated to improve tight quadriceps and hamstrings to prevent and improve LBP. Supinated foot and flat foot (pes planus) have been considered risk factors for overuse injuries of the lower extremities.^{63–65} One systematic review performed by Bromley *et al* reported that the most frequently injured areas in boxers were the head/face (45.8%), wrist (12%) and low back (7.8%).⁶⁶ Boxers tended to have a higher percentage of low medial longitudinal arch of the foot, supinated leg-heel angle in this study. As far as we know, there is no study evaluating the alignment and posture of the foot in boxers. Therefore, it was impossible to describe why boxers had higher prevalence of lower medial longitudinal arch of the foot and supinated leg-heel angle in this study. Further studies will therefore be required to evaluate the correlation between foot morphology and injuries in boxers because the medial longitudinal arch of

Table 3 Results of the orthopaedic medical examinations (categories 2–6)

Variable	Total (n=323)	Boxers (n=110)	Canoeists (n=67)	Weightlifters (n=61)	Track and field athletes (n=85)
GJL	1.7±1.2	1.8±1.2	1.7±1.3	1.5±1.0	1.9±1.4
FFD, n (%)	56 (17.3)	19 (17.3)	16 (23.9)	12 (19.7)	9 (10.6)
SLR (R), °	75.3±12.1	78.9±10.7	77.0±12.8	69.3±13.7	76.0±11.0
SLR (L), °	75.4±11.8	78.2±8.8	76.9±13.0	69.9±14.2	76.5±11.0
Thomas test (R), n (%)	45 (13.9)	15 (13.6)	9 (13.4)	6 (9.8)	15 (17.6)
Thomas test (L), n (%)	44 (13.6)	14 (12.7)	11 (16.4)	5 (8.2)	14 (16.5)
Ely's test (R), n (%)	85 (26.3)	19 (17.3)	16 (23.9)	28 (45.9)	22 (25.9)
Ely's test (L), n (%)	75 (23.2)	19 (17.3)	11 (16.4)	27 (44.3)	18 (21.2)
Dorsiflexion of the ankle joint (R), °	13.4±6.7	14.7±7.8	13.2±6.6	11.8±6.2	13.7±6.2
Dorsiflexion of the ankle joint (L), °	12.5±6.1	13.8±6.9	13.1±5.5	11.3±5.7	11.7±6.3
Q angle (R), °	11.8±4.8	10.2±4.7	12.9±4.4	11.9±4.5	12.0±5.5
Q angle (L), °	11.2±4.3	10.5±4.5	11.4±3.8	11.7±3.7	11.2±5.1
Leg heel angle (R), n (%) pronation	55 (17.0)	16 (14.5)	16 (23.9)	8 (13.1)	15 (17.6)
Supination	52 (16.1)	29 (26.4)	6 (9.0)	6 (9.8)	11 (12.9)
Neutral	216 (66.9)	65 (59.1)	45 (67.2)	47 (77.0)	59 (69.4)
Leg heel angle (L), n (%) pronation	63 (19.5)	16 (14.5)	19 (28.4)	9 (14.8)	19 (22.4)
Supination	53 (16.4)	29 (26.4)	6 (9.0)	6 (9.8)	12 (14.1)
Neutral	210 (65.0)	65 (59.1)	42 (62.9)	46 (75.4)	57 (67.1)
Circumferential length of the thigh (R), cm	46.3±3.4	42.7±3.1	45.6±2.5	49.8±3.3	47.1±4.5
Circumferential length of the thigh (L), cm	46.5±3.5	43.4±3.7	45.6±2.5	50.0±3.3	46.9±4.4
Circumferential length of the calf (R), cm	35.7±2.6	33.9±2.3	35.0±1.9	36.7±2.9	37.3±3.3
Circumferential length of the calf (L), cm	35.6±2.6	33.9±2.3	35.0±1.9	36.5±3.0	37.1±3.2
Low medial longitudinal arch of the foot (R), n (%)	136 (42.1)	53 (48.2)	24 (35.8)	25 (41.0)	34 (40.0)
Low medial longitudinal arch of the foot (L), n (%)	138 (42.7)	54 (49.1)	26 (38.8)	25 (41.0)	33 (38.8)

Data presented as mean±SD unless otherwise indicated.

The value in FFD, Thomas test and Quadriceps hip-up test shows the number of patients with positive findings.

BMI, body mass index; FFD, finger floor distance; GJL, generalised joint laxity; L, left; R, right; SLR, straight leg raising.

the foot was assessed only as the navicular height, without the analysis of X-rays in the present study.

There were several limitations to the present study. First, the young amateur athletes enrolled in this study had high-level performance in their respective sports, therefore the generalisation of the results of this study to all young amateur athletes may not be appropriate. Second, the study only assessed young athletes in four sports activities (boxing, canoeing, weightlifting and track and field), therefore, we could not evaluate young athletes who participated in other sports activities. Third, orthopaedic medical examinations in this study were originally developed in our country and it remains unclear whether the system or the assessment of the orthopaedic medical examinations in this study was appropriate. Fourth, plain radiographs, such as lateral weight-bearing radiographs, were not taken to evaluate flat foot. The orthopaedic medical examination is a screening test, therefore, performing X-rays for all individuals would be an excessive procedure with exposure to radiation and

would not be cost-effective. Palpation and measurement of the height of the navicular tuberosity have been shown to provide valid information regarding the structure of the medial longitudinal arch,⁶⁷ therefore, this method may be appropriate as a screening test for the flat foot. Despite these limitations, the present study showed the significance of orthopaedic medical examinations for young amateur athletes in order to detect their injuries and pain as soon as possible and to educate young athletes, their parents and coaches.

CONCLUSIONS

We herein first reported the results of orthopaedic medical examinations (screening) of a total of 323 young amateur athletes (boxers, canoeists, weightlifters and track and field athletes). Among these athletes, 5.3% had received orthopaedic treatment, and 19.9% of the young athletes, who had not received orthopaedic treatment, were considered to require management by orthopaedic



doctors. In addition to facilitating the early detection and treatment of acute and chronic injuries in young amateur athletes, the performance of orthopaedic medical examinations provides an opportunity to educate such athletes and maintain their well-being and would be therefore an important screening method.

Contributors TY collected data. TY and TT mainly drafted the manuscript, and NY, MN, TO, YM and EC supervised it. All authors performed orthopaedic medical examinations in this study. All authors had complete access to all data used in this study and take responsibility for its accuracy. All authors have read and approved the final manuscript.

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Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Obtained.

Ethics approval Ethical approval of this study was obtained from the institutional review board at Miyazaki University Graduate School of Medicine (Approval number 2015-101).

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement All data relevant to the study are included in the article or uploaded as supplementary information. Data are available upon reasonable request.

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