

Gymnastic Formation-related Injury to Children in Physical Education

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Objective: Current data indicate that the rate of trauma in children during gymnastic formation is increasing, especially while creating a structure with a certain height, such as the human pyramid. The goal of the present study was to clarify the clinical characteristics of these injuries.

Methods: In this single-institution review, all children treated for a gymnastic formation-related injury at Nippon Medical School Hospital from 2013 through 2015 were identified through the institution's registry. The injury mechanism was classified, and injury severity, interventions, and outcome were examined.

Results: Eight children were treated for a gymnastic formation-related injury. They were 7 boys and 1 girl aged 10 to 15 years (mean age, 13.1 ± 1.8 years). Neurotrauma ranging from concussion to spinal cord injury without radiographic abnormality occurred in 6 patients (75%). No intracranial hemorrhagic lesions were detected. The Glasgow Coma Scale score on arrival was 15 in all 8 patients, and neurological deficits were present in 1 patient. No patient required surgical intervention. All patients made a full recovery after discharge from the hospital. No patients died. The average follow-up period was 2.1 ± 0.9 weeks.

Conclusions: Neurotrauma is a frequent result of gymnastic formation accidents in children. Healthcare workers and teachers should recognize this type of injury, and public education that targets parents should be introduced. (J Nippon Med Sch 2015; 82: 295–299)

Key words: gymnastic formation, neurotrauma, children, physical education, human pyramid

Introduction

Physical education is an important tool for public health officials to increase the physical activity of school children. Judo, a Japanese martial art, became a compulsory physical education subject for junior high school students in Japan in 2012, despite causing catastrophic head and neck injuries¹⁻³. For physical education at the athletic events of many schools, gymnastic formation is used; one example is the making of a human pyramid, in which the students kneel together in a row or other formation to form a base for another tier of students who kneel or stand on their shoulders, backs, or thighs. The strongest students form the base of the pyramid, and lighter students are usually placed at the top. Gymnastic formation, including the making of human pyramids, can be per-

formed by cheerleaders, circus acrobats, Boy Scouts, or anyone properly trained; however, the height of formations at athletic events has been increasing and can be as much as several meters. Considering such heights and the risk of injury, the highest priority should be the safety of students. However, few studies or case reports have included gymnastic formation-related injuries. Therefore, the aims of the present paper of gymnastic formation-related injuries were to (1) discuss this specific mechanism of injury, which can cause serious neurotrauma; (2) identify risk factors and suggest strategies for injury prevention; and (3) investigate neurological injuries, classification, and outcomes of gymnastic formation accidents involving children.

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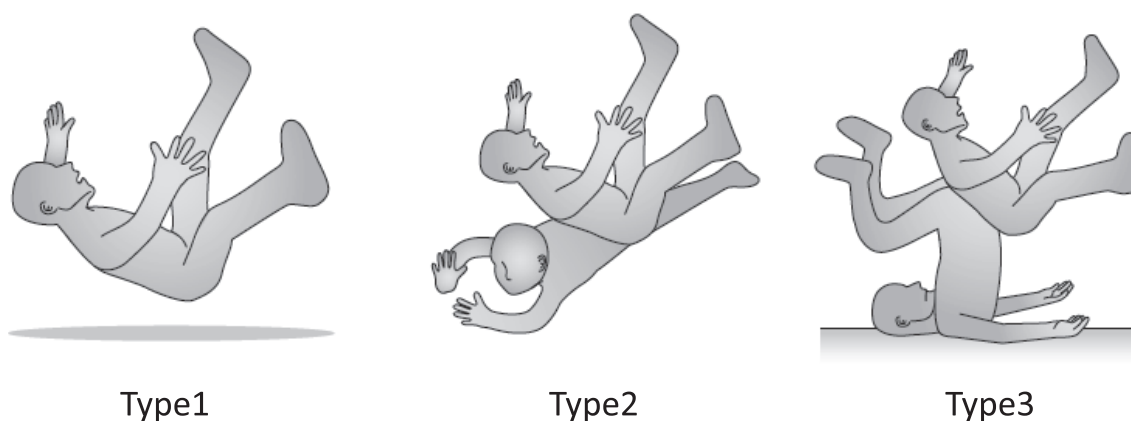


Fig. 1 Types of gymnastic formation-related injuries

Materials and Methods

Patients in this single-institution review were identified from the medical records of our hospital's general medical center, which treats more than 50,000 emergencies per year in a metropolitan area. Study criteria included the presence of a gymnastic formation-related injury, in a patient 16 years or younger at the time of accident, from 2013 through 2015. A gymnastic formation-related injury was defined as an injury resulting from a fall or other mechanism while forming any structures in gymnastic formation. These patients were retrospectively identified with our hospital's database, which tracks all trauma-related presentations of pediatric patients seen in the general medical center. Institutional review-board approval was obtained. Patients' medical charts were reviewed and included all physician and nursing notes, history and physical examination findings, reports of consultations, progress notes, radiology reports, operative and procedural notes, discharge summaries, and follow-up office records, if available. Demographic data, including age and sex, for each patient were collected. Clinical and other injury-related data collected included date of injury, mechanism of injury, level of tier within formation, specific injuries with imaging, whether there was initial loss of consciousness, initial Glasgow Coma Scale score, presence of neurological deficits, any required operative interventions, and the final outcome of the injury. Head injury was defined as either a concussion or abnormal findings on computed tomography of the head.

Gymnastic formation-related injuries were classified into 3 types (Fig. 1). Falling to the ground (type 1 injury) tended to occur to students who had been standing at the top of any types of structures such as a human pyramid, a human tower. Being squashed by pressure

(type 2 injury) tended to occur to students who had been kneeling or standing on the ground to form a base for an upper tier of students. Falling head first upon a hyperflexed neck and being fallen upon by higher-tier students (type 3 injury) tended to occur when students formed a mid-level tier by kneeling or standing on the shoulders, backs, or thighs of lowest-tier students and usually did not have enough space to evacuate when the formation collapses.

Results

Demographic Data

From 2013 through 2015, 8 children were treated for a gymnastic formation-related injury. Of these children 5 were from a junior high school and 3 were from a primary school. The children were 7 boys and 1 girl and aged 10 to 15 years (mean age, 13.1 ± 1.8 years) (Table 1).

Head Injuries and Other Types of Neurotrauma

Head injuries occurred in 3 patients (37.5%). No intracranial hemorrhagic lesions were detected. Loss of consciousness was not observed in any patients. Upon arrival to the emergency room, all patients had a Glasgow Coma Scale score of 15. Five patients (62.5%) experienced a neck injury ranging from neck sprain to spinal cord injury without radiographic abnormality. One patient had neurological deficits, and 2 patients sustained orthopedic injuries requiring fixation. Two patients (25%) were admitted to the hospital for definite treatment, but no patient required neurosurgical intervention. Type 1 injuries occurred to 2 students in whom concussion was diagnosed and 1 student who had a fractured arm. Type 2 injuries tended to cause orthopedic injuries. Type 3 injuries caused a spinal or neck injury in 3 students, a fracture in 1 student, and bruise on the trunk in 1 student (Fig. 2).

Table 1 Summary of features of 8 children with gymnastic formation-related injury

Case	Age (years)	Gender	Type	Follow Up (weeks)	Diagnosis	Management	Admission	Outcome
1	12	female	1	1	concussion	observation	no	good recovery
2	15	male	2	1	bruise on trunk, concussion, neck sprain	hard collar	no	good recovery
3	10	male	3	1	neck sprain	hard collar	no	good recovery
4	14	male	1	1	concussion, neck sprain	observation	no	good recovery
5	11	male	3	8	SCIWORA	hard collar	yes	good recovery
6	14	male	3	1	abdominal trauma, neck sprain	observation	no	good recovery
7	14	male	2	1	fracture	fixation	no	good recovery
8	14	male	1	2	fracture	fixation	yes	good recovery

SCIWORA, spinal cord injury without radiographic abnormality

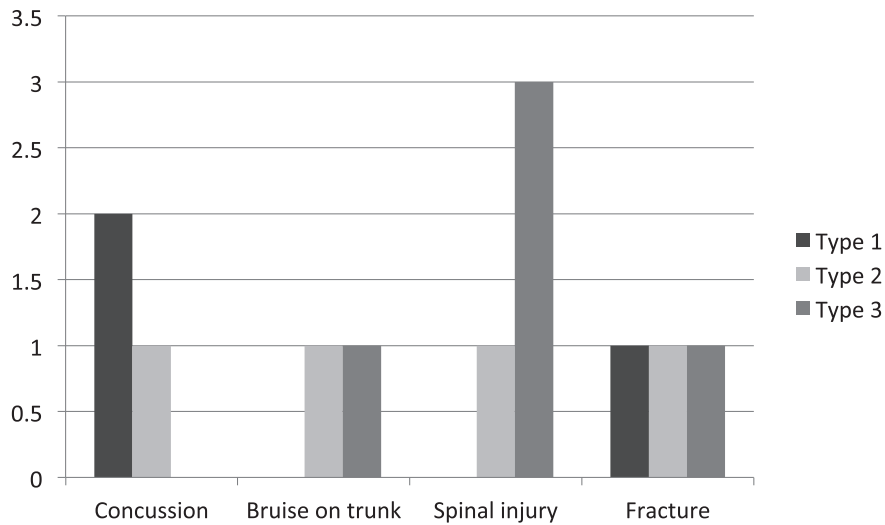


Fig. 2 Type distribution of gymnastic formation-related injuries with a final diagnosis of trauma

Outcomes

None of the patients died. All patients made a full recovery; however, 1 patient (12.5%) required follow-up observation for neurological deficits due to spinal cord injury without radiographic abnormality. The average follow-up period was 2.1 ± 0.9 weeks.

Discussion

The increase in the number of gymnastic formation-related injuries appears to be due to the increased height of the formation, which can be greater than 5 m. Such a height can be achieved by even primary school students; however, the existence of such height of formation this was not evident in our findings. According to the database of the Japan Sport Council School Safety Department⁴, which provides medical expenses for treating injuries and accidents of school children occurring while under school supervision, recorded 6,500 annual gymnastic

formation-related injuries among primary school students and 1,800 injuries among junior high school students in 2014. Of recorded 6,500 injuries, 1,560 were fractures. No data specifically focusing on human pyramid-related injuries were observed.

In the present study we found that 8 injuries of children were related to gymnastic formation. We classified the cause of damages as 1 of 3 types depending on the position of the injured student in the gymnastic formation. Typically, children of lower weight climb onto the shoulders of students in a lower tier. These children are more likely to fall to the ground and having their heads struck. Therefore, head injury was common in type 1 gymnastic formation-related injury. Despite the strongest students producing the base of the formation, the weight of students in an upper tier still has a great potential to cause severe injury when the formation collapses. In type 2 injuries, students were located at the base of the forma-

tion and were squashed simply by pressure. These students tended to have orthopedic injuries, including a sprain of any joint, fracture, and dislocation, rather than neurotrauma. Type 3 injuries can be extremely severe. Students involved in this type of injury were usually in the middle tier of a formation. The center of gravity of the formation is higher, which could result in increased momentum once a fall begins. If students have not been sufficiently instructed to make firm connections with each other, the students in higher positions can fall onto students in lower tiers. In addition, students in the middle tiers do not have enough space for evacuation once the formation collapses. In our cases, two students with neurological deficits fell head first onto their hyperflexed neck and the hyperflexion of the neck could have been subsequently increased when other students fell onto those in lower tiers whose necks were already hyperflexed.

There are currently no instruction guidelines or adequately trained or certified gymnastic formation instructors. Gymnastic formation, including the creation of human pyramids, without proper instruction must be avoided in physical education activity. Uchida⁵ has originally emphasized public awareness of serious injuries resulting from gymnastic formation from his own detailed researches. Shields et al.⁶ have reported in their study that cheerleading should be recognized as an important source of injury, especially for girls. They recommended that a set of uniform rules and regulations directed at increasing the safety of cheerleading be implemented and universally enforced. Smith⁷ has investigated trampoline-related injuries and concluded that prevention strategies are inadequate. Smith⁷ has also recommended that a national trade-in campaign be conducted to decrease the number of existing backyard trampolines. On the basis of their national surveillance study, Nelson et al.⁸ reported that identifying patterns of physical education-related injuries is the first step toward preventing them, and that education pertaining to injury prevention for physical education class activities, especially those with a high risk of injury, should be made a priority.

According to the judgment of the Fukuoka District Court, in 1990, a lack of appropriate instruction in a physical education class resulted in the collapse of a human pyramid and the serious disability of a 17-year-old boy. The court stated that the human pyramid's 8 tiers and its height of 5 m were dangerous, that the risks should have been obvious to teachers and the school, and that the decision to allow students to create a human

pyramid of 8 tiers was careless. No measures had been in place to minimize risk, and the teachers were found responsible for the disability of the boy because of insufficient technical guidance to the students as well as to themselves. The teachers were ordered to pay compensation of approximately 111.5 million yen.

We suggest that the height of a gymnastic formation be decreased to lower to avoid serious complications. Also, teachers, coaches, and assistants must confirm that all students are stable enough to continue maintaining the formation, and if even 1 student claims to be unable to endure any type of burden from that performance, it must be discontinued. Safety training and certification programs should be required of all instructors of any type of gymnastic formation, including a human pyramid. Finally, the establishment of a database for gymnastic formation-related injuries would facilitate the development and evaluation of injury-prevention strategies based on epidemiologic evidence^{9,10}.

This study has a limitation. Because this study was retrospective, detailed information was not always available in the patient charts.

Conclusion

Our experience suggests that gymnastic formation can cause severe injury. Currently, such a program would be still a regular part of physical education and would include recommendations regarding the appropriate height of a gymnastic formation as well as creating and updating an official manual for the teachers on the creation of gymnastic formations. Also, we believe that emergency physicians should partner with neurosurgeons, orthopedic surgeons, and pediatric healthcare providers to create an injury-prevention campaign targeting parents, school healthcare personnel, and teachers to prevent school students from unexpected serious injuries.

Acknowledgements: The authors are deeply grateful to Associate Professor Ryo Uchida, of the Sociology of Education laboratory at the University of Nagoya, whose comments and suggestions were invaluable.

Conflict of Interest: The authors declare that they have no conflicts of interest.

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(Received, July 4, 2015)

(Accepted, September 27, 2015)