Are current playground safety standards adequate for preventing arm fractures?

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ABSTRACT

Objective: To assess compliance with current standards of playgrounds where children have sustained a fall-related arm fracture.

Design, setting and participants: Between October 2000 and December 2002, a consecutive prospective series of 402 children aged under 13 years who fell from playground equipment and sustained an arm fracture was identified by emergency department staff in five Victorian hospitals. Trained field testers measured playground equipment height, surface type and depth, and surface impact attenuation factors to determine compliance with safety standards.

Main outcome measures: Playground compliance with current Australian safety standards.

Results: Ninety-eight percent of playgrounds had a recommended type of surface material. The mean surface depth was 11.1 cm (SD, 5.0 cm) and the mean equipment height was 2.04 m (SD, 0.43 m). Although over 85% of playgrounds complied with recommended maximum equipment height and surface impact attenuation characteristics, only 4.7% complied with recommended surface depth.

Conclusion: Playgrounds where children have sustained an arm fracture generally comply with all important safety recommendations except surface depth. Playground fall-related arm fracture requires specific countermeasures for prevention, distinct from head injury prevention guidelines.

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PLAYGROUND-RELATED INJURY is a common childhood occurrence, representing about 6% of all hospital-treated childhood injuries.[1] In Victoria, 22% of children presenting to hospital with playground-related injury are admitted[1] and medical treatment costs are about $7.9 million per year (1996/97).[2]

Most injuries result from a fall from playground equipment located at school, in public parks or at home.[1,3] Upper-limb fracture is the most common injury, accounting for 43% of playground injury presentations to hospital emergency departments and 74% of hospital admissions for playground injury in children.[1]

Risk factors for playground injury include the height of the equipment from which the child falls and the nature of the surface onto which he or she lands.[4-8] Current playground safety standards aim to minimise the risk of potentially fatal head injury, with measures of surface-impact attenuation (peak impact deceleration < 200*g* and head injury criterion [HIC] < 1000) used to define safe playgrounds.[9-12] (For definitions of some key terms, see Box 1.)

Through laboratory-based testing,[13,14] critical head-injury measures have been interpreted in some countries to correspond to maximum equipment heights not exceeding 2.5 m and minimum surface depths of 20 cm.[10,11] Other countries' standards provide key headform impact guidelines without translating these into recommended equipment heights or surface depths.[9,12]

Population-based hospitalisation rates for playground injuries have been increasing steadily in Victoria, with primarily arm fracture, not head injury, driving this trend (Box 2). This is despite the introduction of stricter playground standards in 1996.[11] This trend raises the question of whether playgrounds where children sustain arm fractures comply with current safety standards and, if so, whether current playground safety standards are adequate for preventing arm fractures.

The aim of our study was to investigate the extent to which playgrounds where fall-related arm fractures occur comply with safety standards for equipment height and surface type and depth. The study was part of a larger case controlled study of risk factors for arm fracture.[15]

METHODS

Study population

A consecutive prospective case series study of playground fall-related arm fractures was conducted from October 2000 to December 2002. Emergency department staff at five participating hospitals in Victoria electronically reviewed medical records weekly to identify cases. Our criteria for selection specified children aged under 13 years; falling from fixed playground equipment; located at school or preschool; and resulting in a fracture of the humerus, radius, ulna, or a combination of these bones. Fracture diagnosis was confirmed by a treating physician, and corresponded to ICD-10-AM codes S42.2, S42.3, S42.4, S52, S62.0, S62.1, S62.8 and T10 as seen on x-ray.[16]

On-site interviews

Trained field testers interviewed the children in the playground. Questions aimed to determine the equipment from which the child fell, the equipment height and the playground surface impact location. Child height and weight were measured at interview.

Field measurements and data analysis

Field measurements included equipment height and surface type and depth. The maximum height of the equipment

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1: Glossary of key terms

Drop test: A series of impact measurements conducted by dropping an instrumented headform from the maximum accessible height of a piece of playground equipment to the ground.

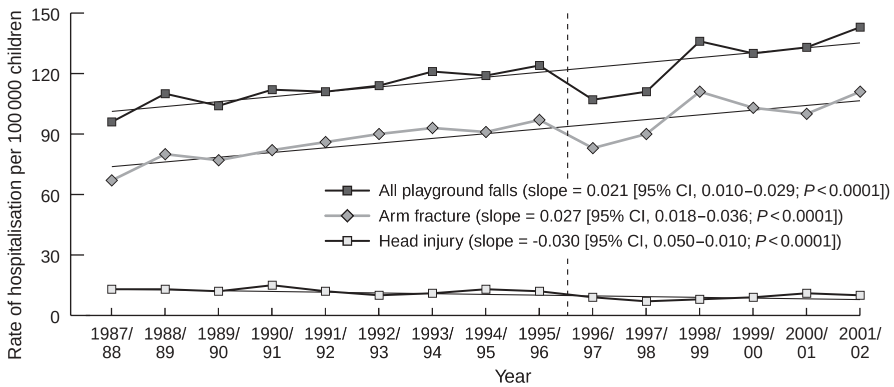
Headform: A head-shaped structure designed for testing the potential effect on the human head of high-impact trauma. A *triaxial accelerometer headform* is one that contains three accelerometers positioned orthogonally to obtain an accurate measure of the deceleration/time trace.

Head injury criterion (HIC): HIC is calculated from the deceleration/time trace of a headform drop test and is a predictor of the probability of fatal head injury. An HIC value ⩾ 1000 is considered indicative of an unacceptably high risk of fatal head injury.

Peak impact deceleration: The maximum deceleration experienced during an initial impact. It is expressed as a multiple of the acceleration constant g (9.8 m/s^2).

Surface impact attenuation: A measure of the degree to which a surface material deforms, on impact, to reduce the amount of deceleration of the impacting object.

2: Trends in rates of hospitalisation for arm fracture and head injury in children who fall from playground equipment, Victoria, Australia*



* The dashed line indicates the introduction of stricter playground safety standards (in 1996).
Source: Victorian inpatient minimum dataset, children aged less than 15 years.

3: Summary of child and playground characteristics in cases of fall-related arm fracture

	n	Mean	SD	Minimum	Median	Maximum
Child characteristics						
Age (years)	402	7.1	1.8	2.0	7.0	12.0
Child height (m)	402	1.28	0.11	0.98	1.27	1.54
Child weight (kg)	402	28.0	7.9	14.0	26.0	60.0
Playground characteristics						
Body mass index (kg/m^2)	402	16.8	2.5	11.9	16.3	26.0
Equipment height (m)	370	2.04	0.43	0.41	2.30	3.70
Surface depth (cm)	361	11.1	5.0	0	10.5	26.0
Peak impact deceleration (g)	198	119	46	36	113	298
Head injury criterion (HIC)	198	615	338	53	517	3311

was measured as the vertical distance from the surface to the highest accessible part of the structure.[17] Surface depth was measured (for loose-fill surfaces only) as the average of three probe readings taken 30 cm apart in a triangle around the surface impact location. If the surface had been modified after the fall, child details were recorded but surface depth and equipment height were excluded.

Peak impact deceleration was measured using a triaxial accelerometer headform (Playground Clearing House MAX G/SI, Phoenixville, Pa) in a standard drop-test procedure.[11] Instrumentation has been previously described and output validated.[15] Headform impact tests were conducted from the maximum height of the equipment. Deceleration/time curves were generated, from which peak impact deceleration and HIC were derived, and the worst outcome of three drop tests was included in the analysis.[11]

As availability of the playground headform was limited, surface impact tests were undertaken in only 50% of playgrounds. Independent *t*-tests were conducted to detect any significant difference between headform-tested and non-headform-tested groups.

We calculated the mean and standard deviation of each variable measured and determined the proportion of playgrounds complying with Australian playground safety standards.[11,17]

Ethics approval

The study adhered to national ethical guidelines.[18] Informed written consent was obtained from the parents of participants.

RESULTS

Participants

There were 624 identified children with playground fall-related arm fracture presenting to the five hospitals during the study period. Of these, 179 (28.7%) were not included in the analysis because their families could not be contacted after five attempts by telephone; 26 (4.2%) and 17 (2.7%), respectively, were from families and schools that declined to participate.

The final series comprised 402 cases (a 64.4% recruitment rate). Participants included 175 boys (43.5%) and 227 girls (56.5%) (for a summary of measurements relating to the group, see Box 3).

Playground surfaces and equipment height

For the 402 playground fall-related arm fractures investigated, 98.0% occurred on recommended surface material, namely tanbark ($n = 389$), sand ($n = 4$) and rubber ($n = 1$). Eight playgrounds (2.0%) had non-recommended surface material: soil ($n = 5$), grass ($n = 1$), mat ($n = 1$) and wood ($n = 1$).

Playground surface modification between the time of the child's injury and the time of measurement (mean, 20.6 days; SD, 10.4 days) resulted in 32 cases (8.0%) being excluded from surface depth and equipment height measurements and analyses. Playground equipment height was thus measured in 370 playgrounds (92.0%). Nine playgrounds had surfaces (eg, grass, rubber) whose depth was not measurable, leaving 361 playgrounds (89.8%) for which surface depth could be reported.

Headform impact tests were conducted in 198 of the 402 playgrounds (49.3%). Playgrounds were excluded from impact testing if tests were conducted before the availability of the borrowed playground headform device (46.3%), if playground surfaces were modified before the field test (3.7%), or if the risk of damage to the headform instrument was high (0.7%). There were no significant differences between the headform-tested and non-headform-tested groups in terms of child age ($t = 0.2$; $P = 0.86$), child height ($t = 0.4$; $P = 0.73$), child weight ($t = 0.4$; $P = 0.70$), equipment height ($t = 1.3$; $P = 0.20$) and surface depth ($t = 1.8$; $P = 0.07$).

Summary results for playground equipment height, surface depth, peak impact deceleration and HIC, where measurable, are presented in Box 3.

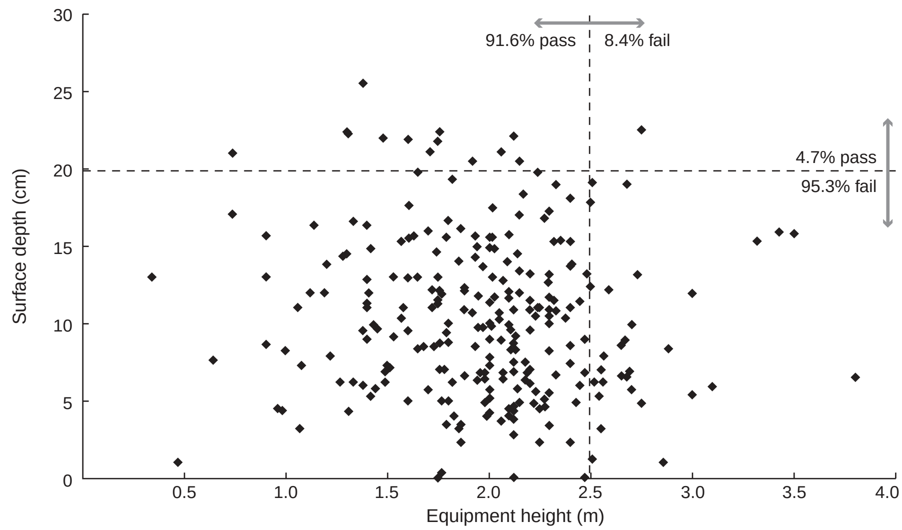
Although the recommended surface material was often installed, only 17 playgrounds (4.7%) complied with the standard recommended 20 cm surface depth (Box 4).

Most playgrounds (91.6%) complied with the 2.5 m equipment height recommendation (Box 4). Thirty of the 31 playgrounds (96.8%) that did not comply with equipment height recommendations also did not comply with surface depth recommendations.

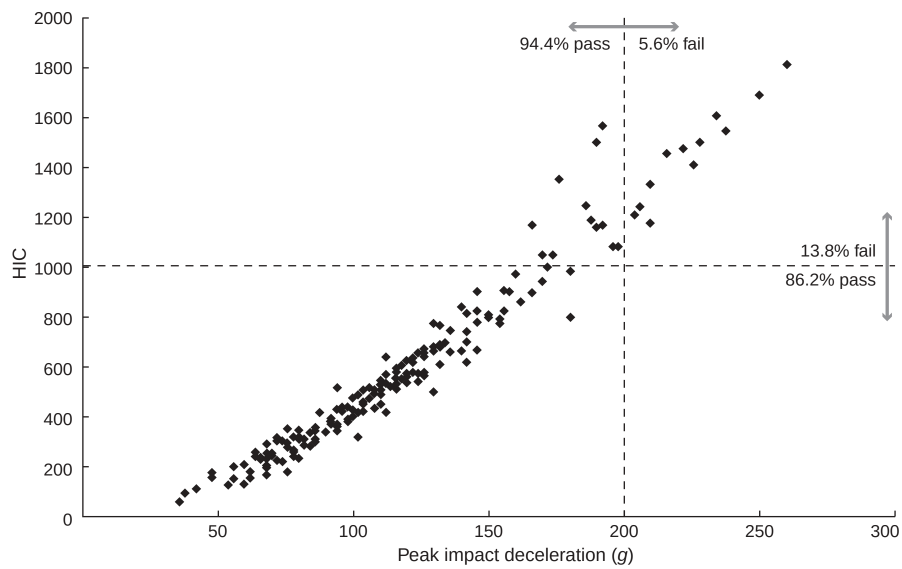
Most playgrounds (94.4% and 86.2%, respectively) complied with the recommendations that peak impact deceleration should not exceed 200g and HIC should not exceed 1000 (Box 5). Notably, only 6.7% of playgrounds in this series that failed surface depth tests also failed to conform with peak impact deceleration guidelines (Box 6).

The degree of compliance of each measured variable with current safety standards is summarised in Box 7.

4: Surface depth and equipment height compliance in 361 cases of arm fracture in children (dotted lines denote recommended limits)



5: Peak impact deceleration and HIC compliance in 198 cases of arm fracture in children (dotted lines denote recommended limits)



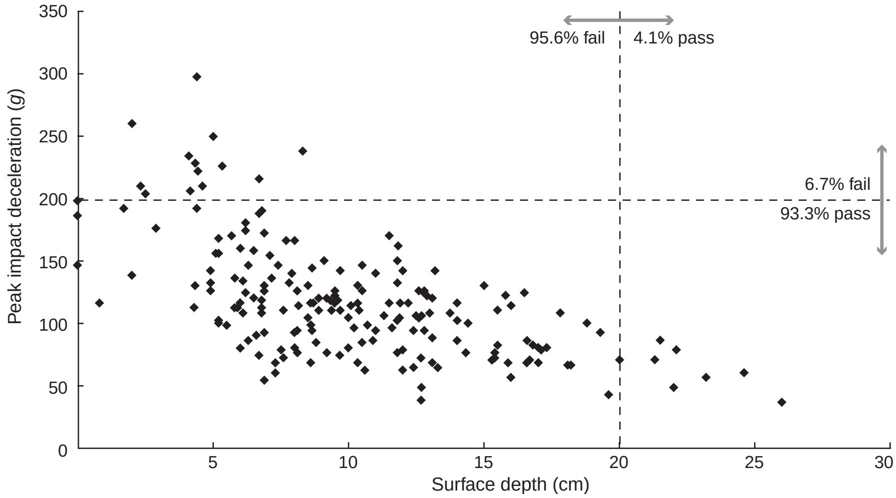
HIC = head injury criterion.

DISCUSSION

The major finding of our study was that over 86% of the playgrounds assessed complied with current Australian standards in terms of surface material type, equipment height, and measures of surface impact attenuation (peak impact deceleration and HIC). The study also established that correct surface material was installed in 98% of playgrounds, although surface depth compliance was poor (4.7%). Another study reported 16% surface depth compliance in NSW council playgrounds,[19] and our own previous audit of 176 pieces of school playground equipment revealed only 5.7% surface depth compliance (unpublished data).

Surface depth recommendations are included in the standard as simplified proxy guidelines to compliance with playground surface impact attenuation requirements. However, surface depth alone is not a reliable predictor of surface impact attenuation. Our results indicate that arm fracture often occurs in playgrounds that comply with current safety

6: Surface depth and peak impact deceleration compliance in 198 cases of arm fracture in children (dotted lines denote recommended limits)



7: Summary of compliance of playgrounds with recommended Australian safety standards[11,17]

Variable	Compliance rate
Equipment height	91.6%
Surface material	98.0%
Surface depth	4.7%
Peak impact deceleration	94.4%
Head injury criterion (HIC)	86.2%

standard impact attenuation guidelines. The mean impact attenuation values (peak impact deceleration, 119*g*; HIC, 615) were well below the currently recommended limits of 200*g* and 1000. This finding implies that current playground safety standards are inadequate to address the risk of arm fracture.

There has been some discussion in Australia and overseas about simplifying the standards for playground equipment by adopting only one of the two measures of surface impact attenuation. However, despite a high correlation between peak impact deceleration and HIC values ($r^2 = 0.92$), reliance on peak impact deceleration measures alone as a critical safety guide may underestimate the risk of playground injury (Box 5). By including specific injury criteria such as HIC, safety standards would define about 8% more playgrounds in this series as non-compliant.

Strengths of our study include the large sample size, the standard protocol under which it was conducted, validated child interviews and validated field measures of peak impact deceleration and HIC. This case series reveals new and important observations that emphasise the need to further investigate risk factors for arm fracture in children who fall from playground equipment. Limitations of our study include the fact that it was conducted primarily on tanbark surfacing and related only to falls from static playground equipment. A lack of statistical power precluded any stratification of results by age groups.

Playground fall-related arm fracture requires specific countermeasures for prevention, distinct from head-injury prevention guidelines. We believe that injury criteria more closely related to the risk of arm fracture should be developed and included in revised playground safety standards to complement HIC as a guide to playground safety.

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COMPETING INTERESTS

None identified.

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