Surface characteristics, equipment height, and the occurrence and severity of playground injuries

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Abstract

***Objectives*—To evaluate whether surface characteristics (absorption level (g-max), material) and the height of play equipment are related to the occurrence and severity of injuries from falls.**

***Setting and methods*—During the summers of 1991 and 1995, conformity of play equipment to Canadian standards was assessed in a random sample (n=102) of Montreal public playgrounds. Surface absorption (g-max) was tested using a Max Hic instrument and the height of equipment was measured. Concurrently, all injuries presenting at the emergency department of Montreal's two children's hospitals were recorded and parents were interviewed. Inspected equipment was implicated in 185 injuries. The g-max measurements (1995 only) were available for 110 of these playground accidents.**

***Results*—One third of falls (35 %) occurred on a surface exceeding 200 g and the risk of injury was three times greater than for g level lower than 150 (95% confidence interval (CI) 1.45 to 6.35). On surfaces having absorption levels between 150 g and 200 g, injuries were 1.8 times more likely (95% CI 0.91 to 3.57). Injuries were 2.56 times more likely to occur on equipment higher than 2 m compared with equipment lower than 1.5 m. Analysis of risk factors by severity of injury failed to show any positive relationships between the g-max or height and severity, whereas surface material was a good predictor of severity.**

***Conclusions*—This study confirms the relationships between risk of injury, surface resilience, and height of equipment, as well as between type of material and severity of injury. Our data suggest that acceptable limits for surface resilience be set at less than 200 g, and perhaps even less than 150 g, and not exceed 2 m for equipment height. These findings reinforce the importance of installing recommended materials, such as sand, beneath play equipment.**

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Playground injuries are among the leading causes of emergency department visits by children.[1–7] Several countries have voluntary standards aimed at making playgrounds safer.[8–12] Two important components of these standards concern surfaces located under equipment and equipment height. Laboratory studies have shown that a life threatening head injury is less likely to occur if the head's peak deceleration during impact does not exceed 200 times the acceleration due to gravity (200 g).[13–16] The most widely used laboratory test method for evaluating the shock absorbing properties of playground surface material involves dropping an instrumented metal headform onto a sample of material and recording the acceleration/time pulse during impact, or surface absorption level (g-max) deceleration. This method, adopted by the American Society for Testing and Material, the Consumer Product Safety Commission, and the Canadian Standards Association has been used to classify surfaces as "safe" or "unsafe" with respect to severe head injury.[11 12 15 17] Fortunately, head first falls rarely occur in playgrounds. Therefore, we question the applicability of the 200 g threshold in the prevention of fractures and moderately severe head injuries. Epidemiological data are needed to estimate the maximum acceptable g-max value for playground equipment in view of preventing these most common playground injuries.

Equipment used to measure the g-max in playgrounds is impractical and very expensive. Therefore, given that the g-max depends on both the maximum height of the equipment as well as the type and depth of the material located underneath, tests were developed to estimate the maximum height acceptable for different types and depth of material. This height, referred to as critical height, is an approximation of the height of a fall below which severe head injury is not likely to occur. We question whether the inclusion of critical height in Canadian and American standards[11 12] is sufficient or whether maximum height of the equipment should also be included as in New Zealand.[9] To answer this question, studies are needed not only to confirm the association previously reported between maximum height and the risk of injury,[4–6 18–20] but also to identify the recommended maximum acceptable height.

The objectives of this study were to evaluate the impact of g-max, equipment height, and type of material on both the occurrence and severity of playground injuries among children. Furthermore, maximum acceptable limits for g-max and height will be proposed.

Methods

STUDY DESIGN

Figure 1 shows a model for the association between different risk factors and the occurrence and severity of playground injuries. The

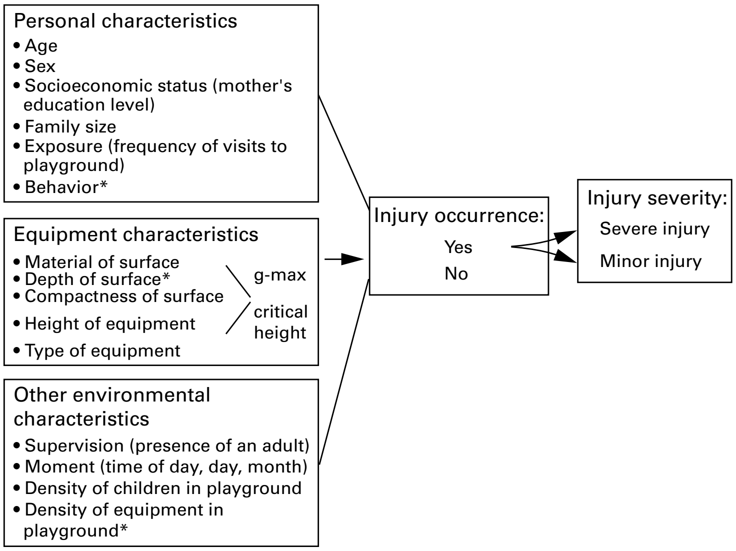

*Figure 1 Theoretical model of occurrence and severity of playground injuries. *Variable not assessed in this study.*

study design chosen to examine these associations is depicted in fig 2. We identified children who sought treatment at an emergency department for a playground injury. During the same period, we studied the conformity of play equipment to Canadian standards, in a sample of Montreal public playgrounds. Therefore, some injuries occurred on equipment inspected in the course of that observation study. Detailed methods and results are provided elsewhere.[6 21 22]

DATA COLLECTION

Injury study

Montreal's two children's hospitals collaborated in this study. Both participate in an injury surveillance program, known as the Canadian Hospital Injury Report Prevention Program (CHIRPP). During emergency department visits, parents completed a standard CHIRPP form describing the circumstances of the injury. These forms were reviewed to identify children, aged 1–14, who were involved in a playground injury from May to September 1991 or 1995. Emergency department statistics were also reviewed to capture cases that may have been missed by the CHIRPP system.

A telephone questionnaire was designed to collect more detailed information regarding the circumstances and consequences of these injuries. A total of 1286 interviews were completed, for a response rate of 91%. Data were collected on the following: age, sex, mother tongue, mother's education level, family size, location (Island of Montreal or not), number of medical consultations for injuries in the past year, supervision (presence of an adult), mechanism of the accident and of the injury, type of playground (home, public, others), equipment type, surface material, time of injury, type of injury, body part injured, mean weekly number of playground visits, and preferred equipment (fig 1). Validity and reliability of the data were assessed and have been reported previously.[6] Type of injury was validated against doctors diagnosis on the CHIRPP form. Verification was done to confirm which equipment was involved in the accident.

Observation study

In 1991, all public playgrounds located on the Island of Montreal were divided into tertiles according to the socioeconomic level of their electoral territory. A stratified random sample was drawn to ascertain that each socioeconomic stratum was represented. In 1995, a random sample of new playgrounds was added to maintain sample representativeness. Play equipment not included in that sample, but reported by the parents as being involved in an injury, were also inspected by our trained observers. The conformity of equipment to Canadian standards was assessed using a validated checklist.[21 22] Observers were blinded as to which equipment was involved in an injury. Surface material was considered not to conform with standards whenever a non-recommended material was present on any part of that surface. The maximum reachable height was defined as the highest point of any piece of equipment. In 1995, g-max measurements were taken in every second playground using a Max Hic device that simulates a child's head first fall. As per recommended protocol, this device was dropped from the three highest points of the play equipment that were accessible to children.[23] Three readings were taken from each point and only the last two were recorded. The average of these six measurements provided the average g-max for the surface.

ANALYTICAL PROCEDURES

Outcome variables

To study risk factors for injury occurrence, the outcome was the fall injury itself (fig 1). The characteristics of equipment involved in an injury (n=110) were compared with all inspected equipment (n=553) in order to verify

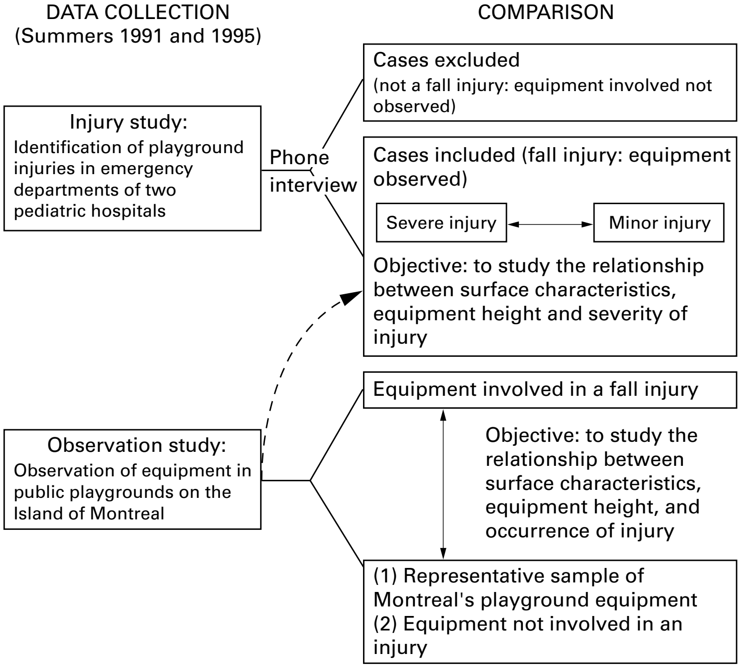

Figure 2 Study design.

whether the characteristics of the former differed from expected. Given that some equipment had been inspected during both data collection periods, analysis regarding occurrence of injury was restricted to the 1995 sample. This decision was supported by the number of equipment involved in an injury (n=110) and by the fact that some variables were only available for 1995.

For the analysis of predictors of injury severity, severity of injury (severe/minor) served as the dependent variable (fig 1). Head injuries were defined as concussions, skull fractures, or contusions as diagnosed by the doctor during the emergency department visit and as reported by the parent. Data collected in 1991 were not sufficiently informative to allow us to distinguish between contusion and concussion, therefore, extra questions were added in 1995. Including contusions as head injury explains why only 50% of head injuries were classified as 2 or 3 on the abbreviated injury scale (AIS).[24] Head injuries and fractures were combined to form the severe injury category. Ninety seven per cent of fractures were considered AIS 2 or 3. All other types of injury (strain, sprain, cut, burns, etc) were classified as minor. A playground injury was defined as an injury sustained as a result of falling from equipment located in one of the inspected playgrounds. These criteria restricted the number of cases and required that data from both years (n=185) be included in the analysis of severity. Data on g-max was collected in 1995 and was, therefore, only available for 110 fall injuries.

Independent variables

The main predictor variables were g-max levels, surface material, and equipment height. Other variables reported in the literature as possible risk factors or confounders, were also considered in the analysis. These included age, sex, mother's education, mother tongue, number of medical consultations, family size, playground use, type of equipment, supervision, and year of data collection.

For the occurrence study, additional variables were derived from the 1991 census data: mean age and percentage of boys in the neighborhoods surrounding the playground; household socioeconomic level; and density of children which provided an indicator for playground use. The relative use of different types of equipment, of various heights and surfaces, was estimated by combining number of visits to the playground by children during the summer, their favorite equipment, and distributions of g, height and material for the different types of equipment. These estimates constitute a proxy for exposure but could not be included in the multivariate model.

Statistical analysis

Univariate analyses were conducted, before categorization of the continuous variables, to verify the normality of their distribution and to identify outliers. Missing values were rare and were replaced by the most likely value or by the mean value. Comparison of equipment involved in an injury and all inspected equipment, according to surface characteristics and height, was done using *t* tests. In order to perform multivariate analysis, a single database was formed (n=645) comprising observations from the representative sample (n=553) and equipment additionally inspected after parents' reports (n=92).

To study risk factors for severity, case-control analyses were performed, with severe injuries serving as cases and minor injuries as controls. For the injury occurrence study, the case series comprised of equipment involved in an injury. Bivariate analyses were conducted to calculate crude odds ratios. Fisher's exact and χ^2 tests were applied to test the strength of relationships. The presence of multicollinearity between the variables was verified. Logistic regression was performed to determine predictors of severity and occurrence of injuries. Adjusted odds ratios, and their 95% confidence intervals, were computed as estimates of risk ratios in the final model.

The 110 accidents studied occurred in 85 different playgrounds and were therefore considered as independent events in the analysis. In order to take into consideration any potential playground effects in the analysis of injury occurrence, some ecologic variables, shown to be associated with the risk of injury in a previous study,[6] were tested in the model.

Data were entered and analyzed using dbase IV and SPSS (Statistical Package for the Social Sciences).

Results

PREDICTORS OF OCCURRENCE OF INJURY

Table 1 presents data for surface material, g-max, and height of equipment involving an injury, corresponding distributions for all the playground equipment inspected in 1995, as well as the proxy for the exposure to different equipment, surface material, g, and height. Adjusted odds ratios are also reported. The final model included: height, type of surface, equipment type, g level as well as the variable density of children in the sector which adjusted for playground use. The proxy for exposure data included in table 1 suggests that the reported associations are unlikely to be explained by the exposure. The results show that the composition of inspected surfaces do not appear to be associated with the risk of injury, whereas the g-max and height of the equipment are. Indeed, the mean height of equipment involved in a fall injury was 2.4 m compared with 1.9 m for all play equipment ($p<0.001$). Compared with the reference category (<1.5 m), the risk of injury was 2.56 times greater on equipment higher than 2 m. The mean g-max was 186 g and 157 g, respectively ($p<0.001$). Surfaces exceeding 200 g were three times more likely to be involved in an injury than those lower than 150.

PREDICTORS OF SEVERITY OF INJURY

A total of 185 fall injuries occurred on inspected equipment. Personal and environmental characteristics of cases are reported in table 2. Approximately 60% of all fall injuries

Table 1 Comparison of surface characteristics and height distributions between all play equipment and equipment involving a fall injury, 1995

Variable	*Average No (%) of use/child/summer*† (n=118)*	*Equipment involving an injury (n=110) (%)*	*All playground equipment (n=553) (%)*	*Odds ratio (95% CI)‡*
Height (m)§				
<1.5	29.5 (36.5)	11	29	1.00
1.5–2.0	19.4 (24.0)	19	28	1.22 (0.48 to 3.06)
>2.0	31.9 (39.4)	70	42	2.56 (1.07 to 6.14)
Surface under equipment¶				
Recommended	41.5 (35.2)	55	39	1.00
Non-recommended	76.5 (64.2)	45	61	0.59 (0.33 to 1.03)
g-max (g)				
<150	64.6 (54.8)	25	55	1.00
150–199	33.5 (28.4)	40	29	1.80 (0.91 to 3.57)
>200	19.8 (16.8)	35	16	3.03 (1.45 to 6.35)
Equipment type				
Climber	28.9 (24.5)	26	26	1.00
Module	10.6 (9.0)	41	17	2.17 (1.14 to 4.11)
Slide	33.1 (28.1)	11	12	1.18 (0.53 to 2.65)
Swing	37.1 (31.5)	16	35	Not available**
Seesaw	8.2 (7.0)	6	10	1.36 (0.51 to 3.65)

*Estimated by adjusting for the relative use of different types of equipment. For height, swings were not included because their height was not available.This variable could not be included in the multivariate analysis.
†Average number of equipment used by one child during a five month period (May–Sept).
‡Estimated by logistic regression with occurence of injury as the dependent variable. Height, surface, g-max, equipment type, and density of children in the playground area were all included in the final model. Mean age of children, proportion of boys in the surrounding area, as well as socioeconomic level of the area were not associated with the risk of injury occurrence and were not retained in the final model. For these analyses, characteristics of equipment involving an injury (n=110) were compared with those not involving an injury (n=534).
§Height was unavailable for swings. It was available for the 93 additional equipment involving an injury and for 356 pieces of equipment in all playgrounds.
¶As assessed by study observers.
**Swings not included in this analysis secondary to missing height information.
CI = confidence interval.

were severe (11% were head injuries, 49% fractures).

Table 2 shows characteristics of case (severe injury) and control (minor injury) series. Initially, 1995 data were used in logistic regression to test g-max. G-max did not emerge as an independent predictor of severity after adjusting for age, type of surface, height, and mother tongue (table 2), and it did not confound the results. Thereafter, data from both years were combined to increase the power of subsequent analyses. Type of surface and height were introduced into the model along with age, sex, mother tongue, number of medical consultations, and year. Mother's level of education, supervision, type of equipment, use of playgrounds, and number of children in the family were also tested in the model. All p values were greater than 0.20 and no important confounding effects were observed. Although their adjusted odds ratios are reported in table 2, these variables were not retained in the final model.

Table 2 Associations between personal and environmental characteristics and severity of fall injuries, 1991 and 1995

		Severity of injury		
Variable	*No (%) of cases* (n=185)*	*Minor (%) (n=74)*	*Severe (%) (n=111)*	*Odds ratio† (95% CI)*
Age (years)				
1–4	59 (31.9)	49.2	50.8	1.00
5–9	83 (44.9)	33.7	66.3	1.92 (0.91 to 4.06)
10–14	43 (23.2)	39.5	60.5	1.85 (0.77 to 4.46)
Sex				
Male	111 (59.6)	35.1	64.9	1.00
Female	74 (40.4)	47.3	52.7	0.59 (0.30 to 1.14)
Supervision				
Yes	126 (68.1)	41.3	58.7	1.00
No	59 (31.9)	37.3	62.7	0.91 (0.42 to 1.98)
Playground use				
Rarely	23 (12.4)	30.4	69.6	1.00
Frequently	162 (87.6)	41.4	58.6	0.51 (0.18 to 1.45)
Type of equipment				
Swing	31 (16.8)	38.7	61.3	1.00
Climber	40 (21.6)	30.0	69.8	1.04 (0.32 to 3.32)
Module	74 (40.0)	43.2	56.8	0.69 (0.22 to 2.13)
Slide	23 (12.4)	52.2	47.8	0.58 (0.15 to 2.24)
Other	17 (9.2)	35.3	64.7	1.46 (0.36 to 5.96)
Type of surface‡				
Recommended	130 (70.3)	43.1	56.9	1.00
Not-recommended	55 (29.7)	32.7	67.3	2.26 (1.05 to 4.87)
Equipment height (m)				
<1.5	24 (13.0)	45.8	54.2	1.00
1.5–2.0	57 (30.8)	43.9	56.1	0.98 (0.35 to 2.79)
>2.0	104 (56.2)	36.5	63.5	1.48 (0.56 to 3.91)
g-max (g)§				
<150	28 (25.0)	28.6	71.4	1.00
150–199	44 (40.0)	29.5	70.5	1.10 (0.31 to 3.92)
>200	38 (35.0)	36.8	63.2	0.57 (0.15 to 2.17)

*Totals may vary owing to missing data.
†The adjusted odds ratios and 95% confidence interval (CI) were estimated using logistic regression with severity of injury as the dependent variable and controlling for surface, height, age, sex, mother tongue, number of medical visits for an injury per year and year of data collection.
‡Type of surface as reported by parents.
§g-max was only collected in 1995 (n=110).The odds ratio was estimated using only 1995 data and the g-max was not a confounder for any other variables in the model.

Type of surface appears to be a good predictor of severity, with children falling onto non-recommended surfaces having 2.3 times greater risk of severe (p<0.04). The risk of severe injury is similar for equipment height between 1.5 and 2 m and that less than 1.5 m. This increases to 1.5 times greater for equipment higher than 2 m (p<0.51).

Mother tongue (French) and number of medical consultations (few) were associated with severity and were included in the final model to control for differences in use of medical services. Similarly, the variable year helped to control for changes over time.

Discussion

This is one of the first epidemiological studies to evaluate the relationship between g-max and the severity and occurrence of playground injuries. Our findings are, to some extent, consistent with laboratory data, and indicate that the g-max is associated with the occurrence of playground injuries. We failed, however, to show a gradient between g-max and severity of injuries from falls. This finding does not invalidate the idea that g-max levels higher than 200 g predict severe head injury. In fact, the laboratory test used to determine g-max mimics a head first fall, and since such situations seldom occur in playgrounds, we were not able to verify this hypothesis directly. Rather, the findings suggest that the g-max is a good predictor of fall injuries independent of the severity of the injury. The risk of injury was 1.8 times greater in the 150–199 g category compared with the reference category (<150 g). This result approached statistical significance and raises questions about the appropriate g level that should be recommended to prevent the occurrence of all types of injuries in playground and not just severe head injuries.

Our results re-emphasize the potential hazards of non-recommended surfaces. Falls on a non-resilient surface were 2.3 times more likely to cause severe injury, even after adjustment. This research strongly suggests that improving surfaces will help reduce the severity of injuries. This study joins others in supporting the use of sand beneath equipment.[2, 20, 25, 26] Other epidemiological studies are necessary to examine the effectiveness of other promising surfaces, such as wood chips and rubber.[5]

The risk of severe injuries tends to be 1.5 times greater for equipment higher than 2 m compared with equipment under 1.5 m ($p<0.51$) and the risk of injury was 2.56 greater ($p<0.001$). In fact, 70% of all injuries occurred on play equipment higher than 2 m, whereas only 42% of all playground equipment exceeded this height. These results support the inclusion of a 2 m maximum height in all standards. Moreover, our results show that the risk of injury and of severe injury were the same for equipment lower than 1.5 m or between 1.5 m and 2 m, and does not support the recommendation by Chalmers *et al* regarding the reduction of the maximum height from 2 m to 1.5 m.[20] We share the same concerns as Mott and colleagues regarding the proposed raising of the maximum fall height from 2.5 to 3.0 m in Europe.[2]

This study has several strengths. First, it establishes a direct link between observations of playground conditions and actual injuries, and it includes g-max measurements for a large sample of equipment on which injury had occurred. Second, a high response rate was achieved. Third, the study considered several control variables for playground injuries. Finally, exposure was taken into consideration and the results are not likely to be explained by a difference in the utilization of equipment of various types and characteristics.

Certain limitations must also be noted. Restricting the sample to pediatric hospitals can affect the relationship between risk factors and severity by introducing selection bias. In fact, for a similar injury different parents may seek medical aid in different places. This potential bias was taken into consideration by controlling for variables previously associated with parental choice of medical consultation,[27] namely age of children, mother tongue, and socioeconomic status. Another effect of restricting our sample to pediatric hospitals is that minor injuries are under-represented. This would dilute any true associations found. Misclassification can also occur in classifying equipment as having been involved in an accident or not. Again, this would limit the chance of finding significant results. Given that our sample was restricted to the Island of Montreal, this misclassification should not be a major problem.

Key points

Reduce the occurrence and severity of playground injuries by:

- Limiting maximum equipment height to 2 m.
- Installing recommended material under equipment.
- Keeping surface resilience (g-max) under 200 g.

A second limitation concerns the specificity of the measurements for surface and height. We took the maximum height of equipment as a proxy for the height of the fall. Additionally, the mean g-max measured during the summer was used as a proxy for the g-max at the fall site the day of the accident. There could be some variation in the g-max score for a given piece of equipment. This lack of precision in measurement is independent of the severity of the injury but may have diluted the association. The meticulous approach of our observers, who classified any combination of recommended and non-recommended surfaces in a six feet perimeter as non-recommended, may have contributed to masking a possible association between material and the occurrence of injuries.

In conclusion, these data provide evidence that g-max is associated with the risk of injury and place into question the 200 g acceptable limit. Sand under play equipment helps reduce the severity of injuries. The maximum acceptable height of equipment should be included in standards, and we propose 2 m (6.7 feet).

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