Adolescents at the skatepark: identifying design features and youth behaviours that pose risk for falls

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ABSTRACT

Background Skateboarding is an increasingly popular leisure activity for youth, yet injuries due to falls are common. This study aimed to identify the features at skateparks and tricks performed by youth that pose an increased risk of falls in skateboarders.

Method Video recordings were unobtrusively taken at a large skatepark of youth designated as young (11–15 years) or old (16–20 years). Videos were coded to identify the popular skatepark features used and tricks performed, and to assign a fall severity outcome rating for each feature and each type of trick attempted. **Results** The results identify features and tricks that pose increased risk of falling for youth at skateparks. **Conclusions** Implications for injury prevention are discussed, including a consideration of environmental (skatepark design) and individual (youth behaviour) factors relevant to reducing skateboarding injuries due to falls among youth.

INTRODUCTION

In most developed nations unintentional injury is the leading cause of preventable death in children under 19 years.¹⁻³ Elementary school children and teens are typically injured outside the home when making decisions about risk behaviours without adult supervisors, with many of these injuries involving play and recreational sports.⁴ Skateboarding is a sport that is gaining in popularity.⁵⁶ With increasing growth of the sport, there has been a dramatic increase in the popularity of skateparks.⁷ Nonetheless, skateboarding is an activity that involves considerable risk of falling and as more skateparks are being built, injuries are emerging as a more pressing issue.^{7 8} The most common injury mechanism is losing one's balance and falling off the skateboard,^{9 10} usually as a result of failing to successfully execute a trick.^{9 11} However, there is little known about the features on skateparks and types of tricks that increase injury risk. The current study addresses this gap by identifying the features preferred and the tricks youth engage in, as well as the frequency and severity of falls.

Medically treated injuries from skateboarding are particularly common for older children and adolescent skateboarders,⁸ ¹² ¹³ possibly because of the types of tricks older youth attempt.¹⁴ In this study, therefore, younger (11–15 years) and older (16–20 years) skateboarders were unobtrusively videorecorded when on a large skatepark, with age group and sex estimated by physical features and dress.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Skateboarding is a popular sport among youth, yet injuries due to falls are common.

WHAT THIS STUDY ADDS

⇒ Videos were unobtrusively taken of youth (11–20 years) at a large skatepark and then coded. Certain features at the skatepark and tricks performed by youth posed an increased risk of falls.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Targeting the design of the built environment and behaviour in it may effectively reduce injuries to youth when skateboarding at skateparks.

METHODS

Participants

Skateboarders (n=526, 96% male) were assigned to one of two age groups (*younger*, n=166, 11–15 years; *older*, n=360, 16–20 years) based on visual assessment of physical characteristics (ie, height and facial features¹⁵). Inter-rater reliability¹⁵ was 92% agreement (kappa=90%) based on 25% of the videos; the data of the primary coder were analysed.

Materials

A tripod and digital video camera were unobtrusively located and recorded youth on the skatepark. Videos were coded using Noldus Observer XT software.

Data gathering procedure

The Silvercreek Skatepark (73 m long \times 19 m wide, with a surface area of 1387 m²) comprises features common to many skateparks (eg, ramp, stairs, grind box) and was divided into seven smaller observable zones that were randomised during each observation day, with the same number of minutes spent observing in each zone.

Video coding

First, visual assessments were conducted to categorise each skateboarder into either the younger or older group, and as male or female (92% agreement, kappa=90%). Then the behaviours of each skateboarder within a zone were coded for feature used (100% agreement between two independent coders based on 25% of the videos) and tricks attempted (94% agreement, kappa=92%); see the

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online supplemental table for details about skatepark features and videos showing common tricks.

A fall severity scale was applied to code anytime youth attempted a trick or fell from their skateboard: 1=skateboarder completed the trick successfully; 2=skateboarder swayed or shuffled the skateboard due to a loss of balance; 3=skateboarder put one foot off of the skateboard; 4=skateboarder put both feet off; 5=skateboarder fell onto part of their body; 6=skateboarder fell and onto their entire body; inter-rater reliability for 25% of videos was 93% agreement (kappa=91%). The data of the primary coder were analysed. Note that for the flat ground feature, usage was not coded when locomoting from one feature to another on the ground. We had intended to also code helmet usage, but this occurred too infrequently to track.

Data preparation and analysis

Part 1

The proportion of children using each feature was computed for each age group, as was the proportion of falls on each feature. An injury risk exposure score was calculated (proportion of use \times proportion of falls), with higher numbers indicating greater fall risk on a given feature.

Tricks were grouped based on movement similarities. The proportion of children in each age group that attempted each type of trick was computed, as was the proportion of falls for each type of trick. The 95% CIs for feature means were calculated via SPSS's 'explore' function. Data are available on request.

Part 2

Data were collapsed across age groups and analysed using SPSS V.26. Analyses included paired Wilcoxon signed-rank tests (ie, data were overdispersed and severity scores were skewed) to compare the success score (max=1.0) and the fall severity scores associated with different features and tricks to the most popular reference group (feature: ground, trick: jump).

Patient and public involvement

There was no patient or public involvement to report for this research.

RESULTS

Part 1: descriptive statistics for each age group Features: most used and fall outcomes

There were six popular (ie, used by at least 10 children at one age) features used by children (see data in table 1). For young skateboarders, a majority used the flat ground (M=74% of young children, SD=44%), with other popular features including the quarter pipe (M=46%, SD=50%) and the ramp (M=47%, SD=50%). Few attempted the grind box, stairs or railing. By contrast, older skateboarders spent the most time on the flat ground (M=71% of older youth, SD=45%), the quarter pipe (M=46%, SD=50%), the ramp (M=51%, SD=50%) and the grind box (M=35%, SD=48%). Few used the railing or the stairs. Thus, many features were popular at all ages, though some varied with age group.

Both groups of skateboarders experienced the same rank order of fall frequency. The highest fall frequency was on the grind box (younger: M=85% fell, SD=25%; older: M=67% fell, SD=36%), followed by the flat ground (younger: M=65% fell, SD=36%; older: M=61% fell, SD=37%), with comparable lower fall frequency (ie, about 35% of youth) for the quarter pipe and the ramp across age groups.

Table 1 Data shown are the mean (*M*) and standard deviation (*SD*)for the percentage of children using (Use) each feature to try a trick,the percentage of tricks that ended in a fall (Fall) and feature Risk (Use× Fall) as a function of age group (n=171 for young skateboarders11–15 years, n=369 for older skateboarders 16–20 years)

	Young			Old		
Feature	Use M (SD)	Fall M (SD)	Risk M (SD)	Use M (SD)	Fall M (SD)	Risk M (SD)
Flat ground	74 (44)	65 (36)	48 (42)	71 (45)	61 (37)	44 (42)
95% CI	(67, 80)	(59, 71)	(41, 54)	(67, 76)	(56, 65)	(39, 48)
Grind box	14 (35)	85 (25)	12 (31)	35 (48)	67 (36)	23 (38)
95% CI	(09, 19)	(75, 96)	(07, 17)	(30, 40)	(60, 73)	(20, 27)
Quarter pipe	46 (50)	34 (35)	16 (29)	46 (50)	35 (37)	16 (31)
95% CI	(39, 54)	(26, 41)	(12, 21)	(41, 51)	(29, 40)	(13, 19)
Railing	1 (8)	1 (0)	1 (8)	9 (28)	79 (34)	7 (24)
95% CI	(00, 02)	NA	(00, 02)	(06, 12)	(67, 92)	(04, 09)
Ramp	47 (50)	36 (42)	17 (34)	51 (50)	41 (39)	21 (34)
95% CI	(39, 55)	(27, 45)	(12, 22)	(46, 56)	(35, 46)	(17, 24)
Stairs	1 (11)	50 (71)	1 (8)	4 (18)	44 (45)	2 (11)
95% CI	(00, 03)	(00, 685)	(00, 02)	(17, 71)	(17, 71)	(00, 03)
95% CIs for means; scores were truncated to 0 for % scores.						

Examination of the injury risk exposure scores (table 1) revealed that younger skateboarders experienced the highest risk on the flat ground (M=0.48, SD=0.42), followed by the ramp (M=0.17, SD=0.34) and the quarter pipe (M=0.16, SD=0.29). By contrast, older skateboarders experienced the highest risk on the flat ground (M=0.44, SD=0.42), followed by the grind box (M=0.23, SD=0.38) and the ramp (M=0.21, SD=0.34).

Tricks: most attempted and greatest fall risk

Examples of the types of popular tricks that occurred are given in table 2. As shown in table 3, younger skateboarders most often engaged in turns (M=61% of youth, SD=49%), with other types of popular tricks occurring less often: jumps (M=49%, SD=50%), slides (M=41%, SD=49%) and flips (M=31%, SD=46%). They seldom tried lip tricks, stalls or other types of tricks. By contrast, older skateboarders mostly did jumps (M=61% of youth, SD=49%) and 'other' types of tricks (M=53%, SD=50%), with other popular tricks including: slides (M=47% did these, SD=50%), turns (M=42%, SD=39%) and stalls (M=30%, SD=46%). Notably, older skateboarders engaged in a much greater range of types of tricks, designated as 'other' (see table 2). Thus, some types of tricks were popular at all ages, and others varied with age.

Younger and older skateboarders experienced similar rank ordering of fall frequency (table 3). The highest fall frequency for younger skateboarders was flips, with 94% of youth falling when they tried these (SD=17%), followed by slides (M=67% fell, SD=42%), jumps (M=42%, SD=41%) and lip tricks (M=35%, SD=44%). Similarly, older skateboarders also experienced the highest fall frequency with flips (M=81% fell, SD=32%) and slides (M=72%, SD=35%), but with several other types of tricks showing similar lower levels for falling: stalls (M=38% fell, SD=43%), jumps (M=36%, SD=39%) and lip tricks (M=35%, SD=43%). Thus, both slide and flip tricks were high-risk tricks at both ages.

Younger skateboarders experienced the highest fall risk when attempting flips (M=0.29, SD=0.45), followed by slides (M=0.27, SD=0.42) and jumps (M=0.20, SD=0.35); similarly for older skateboarders (see table 3). Thus, the exposure risk

Table 2 Trick categories and examples				
Trick category name	Description and examples			
Jump tricks	Tricks that involved a skateboard jump. This includes ollies and Indy grabs.			
Flips	Tricks that involved the jump and flip of the skateboard. This includes kickflips and heelflips.			
Lip tricks	Tricks that involved balancing on the lip of a feature (eg, quarter pipe). This includes half cab rock to fakie, full cab rock, rock and roll, rock to fakie and any other lip trick observed.			
Turns	Tricks that involved the turning of the skateboard. This includes front kickturns, back kickturns and axel pivot to tail.			
Slides	Tricks that involved the board sliding on the feature. This includes grind, slide and manual.			
Stalls	Tricks that involved the skateboard stalling/suspended in a position. This includes tail stall, 50–50 stall, drop in and axel to drop in.			
Other	Tricks that did not meet other criteria. This includes biebelheimer, nollie shove it and fakie fs 180.			

associated with different tricks was mostly consistent across age groups.

Part 2: fall severity scores collapsed across age groups Features

The flat ground was set as the standard because it was the most popular feature at both ages. All comparisons were conducted via Wilcoxon signed-rank tests.

Success frequency

The frequency of success for popular features was compared with that of the flat ground. As shown in table 4, trick attempts on the ramp were significantly more successful (M=66% of tricks, SD=37%) than tricks on the flat ground (M=38% success, SD=37%), Z=5.37, p<0.001, r=0.39. Success in performing

Table 3 Data shown are the mean (*M*) and standard deviation (*SD*) for the percentage of children doing (Do) each trick type, experiencing a fall (Fall) and exposure risk, as a function of age group (n=171 for young skateboarders 11–15 years, n=369 for older skateboarders 16–20 years)

	Young			Old		
Tricks	Do M (SD)	Fall M (SD)	Risk M (SD)	Do M (SD)	Fall M (SD)	Risk M (SD)
Jumps	49 (50)	42 (41)	20 (35)	61 (49)	36 (39)	22 (35)
95% Cl	(41, 56)	(33, 51)	(15, 26)	(56, 66)	(31, 41)	(18, 25)
Flips	31 (46)	94 (17)	29 (45)	46 (50)	81 (32)	37 (46)
95% Cl	(24, 38)	(89, 99)	(22, 36)	(40, 51)	(76, 86)	(32, 42)
Slides	41 (49)	67 (42)	27 (42)	47 (50)	72 (35)	34 (43)
95% Cl	(33, 48)	(57, 77)	(21, 34)	(42, 52)	(67, 78)	(29, 38)
Turns	61 (49)	20 (35)	12 (29)	42 (49)	11 (26)	5 (18)
95% CI	(54, 69)	(13, 27)	(08, 17)	(37, 47)	(07, 15)	(03, 07)
Lip tricks	12 (32)	35 (44)	4 (19)	13 (34)	35 (43)	4 (18)
95% CI	(07, 17)	(15, 56)	(01, 07)	(09, 16)	(23, 47)	(02, 06)
Stalls	28 (45)	26 (38)	7 (23)	30 (46)	38 (43)	12 (29)
95% CI	(21, 35)	(16, 37)	(04, 11)	(25, 35)	(30, 46)	(09, 15)
Other	39 (49)	0 (0)	0 (0)	53 (50)	4 (53)	2 (39)
95% CI	(32, 47)	NA	NA	(48, 58)	(00, 11)	(02, 06)

95% CIs for means; scores were truncated to 0 for % scores.

Table 4Proportion of successful tricks (1.0 would indicate every trickwas successfully completed) and the mean (*M*) and standard deviation(SD) for fall severity scores (max=6.0), collapsed across ages (n=540)

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Contrasts	Success M (SD)	Severity score M (SD)
Features		
Flat ground†	0.38 (0.37)	4.28 (0.74)
Quarter pipe	0.66 (0.37)*	4.42 (0.81)
Grind box	0.30 (0.35)*	4.44 (0.78)
Ramp	0.61 (0.40)*	4.43 (0.80)
Railing	0.20 (0.33)*	4.86 (0.57)*
Stairs	0.55 (0.45)	4.49 (1.30)
Tricks		
Jump‡	0.63 (0.39)	4.26 (0.88)
Flip	0.16 (0.29)*	4.74 (0.54)*
Lip	0.65 (0.43)	4.41 (.93)
Turn	0.85 (0.30)*	3.76 (0.74)*
Slide	0.29 (0.37)*	4.09 (0.92)
Stall	0.65 (0.42)	4.53 (0.76)
Other	0.97 (0.46)*	4.61 (.62)*

*Significant contrasts, determined via Wilcoxon signed-rank tests, are at p<0.05. +Only the top six popular features were contrasted, with flat ground set as the standard.

*Tricks were collapsed into groupings for contrasts, with the jump group set as the standard.

tricks on the quarter pipe (M=66% success, SD=37%) also was significantly higher than that for the flat ground, Z=5.61, p<0.001, r=0.42. In contrast, the grind box feature had a significantly lower success score (M=30% success, SD=35%) than the flat ground (Z=-3.37, p<0.001, r=0.30), as did the railing (M=20% success, SD=33%), Z=-3.59, p<0.001, r=0.73. The frequency of success on stairs did not significantly differ from the flat ground. Thus, the grind box was a high-risk feature for falls for skateboarders across ages.

Severity scores for unsuccessful trick attempts

As shown in table 4, the severity scores indicated that falls tended to result in the skateboarder stepping off the board. The majority of unsuccessful tricks did not result in differential severity scores across different features when compared with the flat ground, the exception being tricks on the railing which showed significantly greater severity for falls (M=4.86, SD=0.57) than on the flat ground (M=4.28, SD=0.74), Z=5.61, p<0.001, r=0.54.

Tricks

The jump was set as the standard because it was the most popular trick at both ages. All comparisons were conducted via Wilcoxon signed-rank tests.

Success frequency

The frequency of success for popular tricks was compared with that for jumps. As shown in table 4, the flip tricks resulted in significantly lower success in comparison to jump tricks (M=16% and 63% success, SD=39% and 39%, respectively), Z=-8.53, p<0.001, r=0.71. Slide tricks also resulted in significantly lower success (M=29%, SD=37%) in comparison to jump tricks, Z=-8.20, p<0.001, r=0.64. By contrast, turn tricks resulted in significantly greater success (M=85% success, SD=30%) compared with the jump tricks (Z=4.61, p<0.001, r=0.38)], as did other tricks (M=97% success, SD=46%), Z=8.77,

p < 0.001, r = 0.65. However, there was no significant difference between the frequency of success on the remaining three trick groups compared with the standard (jump tricks). Overall, flip tricks were the most likely of all the tricks to lead to a fall.

Severity scores for unsuccessful trick attempts

Flip tricks produced a significantly higher fall severity score (M=4.74, SD=0.54) in comparison to jump tricks (M=4.26, SD=0.88), Z=3.82, p<0.001, r=0.40, as did 'other' tricks (M=4.61, SD=0.62), Z=2.36, p=0.018, r=0.24. In contrast, turn tricks had significantly lower severity scores (M=3.76, SD=0.74) in comparison to jump tricks, Z=-2.69, p=0.007, r=0.52.

DISCUSSION

Skateparks can be a sociable place for youth to exercise and participate in activities they enjoy.^{7 16 17} However, they also contain a combination of concrete and metal features with surfaces that can cause significant injury when falls occur. The present study addressed notable research gaps relevant to skatepark design and the tricks that youth attempt on the skatepark that increase risk of falls.

In terms of skatepark design, there are no universal guidelines or safety standards and we located only three reports that are relevant. One focused on how to limit flaws (https:// publicskateparkguide.org/design-and-construction/factors-ofskatepark-design/). The two other reports were written from an insurance perspective and considered risk management and accident reporting (https://www.emcins.com/losscontrol/techsheet/ skate-park-design-and-safety; https://www.emiia.org/files/miia skatepark_guidelines_2008_edition.pdf). The present findings suggest a number of conclusions about features that are relevant to the design of skateparks. The flat ground was the most popular area at both ages, along with the quarter pipe and ramp features. The pattern of feature usage by age, however, suggests that the grind box is more popular with older experienced skateboarders than younger ones. A differential pattern of feature usage by age could be reflected in how skateparks are designed. For example, features might be grouped together strategically to encourage younger skateboarders in one region and older skateboarders in another. Segregating ages by design might reduce imitation of risky tricks performed by older skateboarders that are viewed by younger skateboarders but are beyond their skill set. Youth imitating peers who are modelling risk behaviours during play is a risk factor for injury.^{18–21}

With regard to designing for safety, at both ages, a majority of skateboarders (about 72%) used the flat ground and fall outcomes occurred at comparably high instances (about 63% of youth fell). Although the flat ground poses no inherent risk due to design characteristics, skateboarders were obviously able to create risk by attempting tricks, including flips, jumps and turns. Skateboarders' desire to master new tricks that challenge their capabilities may contribute to explain this finding.²² For youth at both ages, the quarter pipe and ramp also were popular, though to a lesser degree (45–51% of youth), and fall outcomes on these features did not vary by age, with approximately 37% of skateboarders falling. Additionally, approximately 35% of older youth also used the grind box, with 67% falling; young skateboarders also had a high frequency of falls on the grind box (85% fell) though not many used this feature (14%). It may prove useful to moderate risk of falling if features are differentially coded across the skatepark to suggest difficulty levels, much like what is done on ski hills. In sum, three features were popular at both

ages and associated with high to moderate frequency of falls: the flat ground, the quarter pipe and the ramp. The grind box also was a high-risk feature for falls at both ages, though it was more often used by older than younger skateboarders, suggesting some degree of experience and skill level was judged to be needed before a skateboarder attempted use of that feature. Applying these findings to the design of skateparks, the results suggest that some features are seldom used (stairs, railings), others are popular at all ages (flat ground, quarter pipe, ramp) and some are more popular for more experienced older skateboarders (grind box).

Falls occur on virtually all features (see table 1). However, youth generally fall more frequently on some features (flat ground, grind box) than others (quarter pipe, ramp), with certain features posing differential risk of falls for older skateboarders (railing). Suffice it to say, limiting to those features used by at least 10% of skateboarders herein (table 1) suggests that if a skatepark includes both a quarter pipe and ramp feature then there will likely be a lower risk of falls than if there is a grind box and flat ground as the primary features. Including railings and stairs appeals more to older than younger skateboarders but these are high-risk features for falling by these users. Applying these findings in the design of skateparks could be an effective approach to moderate risk of fall injuries from skateboarding.

With regard to tricks, at both ages youth tended to favour the same tricks, and both slide and flip tricks were high-risk tricks that resulted in an elevated frequency of falling (67-94%) of youth fell). The fact that both younger and older youth showed the same rank ordering of fall frequency as a function of trick type suggests that experience skateboarding may have limited impact to reduce fall risk. Rather, what may matter is the type of trick attempted, with some types elevating fall risk more than others. Experience with a recreational activity often leads youth to engage in more risk-taking behaviours, which essentially counteracts any possible reductions in injury risk that might accrue with improvements in skill level from accumulated experience.²³ It may be, therefore, that reducing skateboarders' risk of injuries resulting from falls during these high-risk tricks may require designing skateparks in ways to minimise the occurrence of these tricks (environment modification) and to identify ways to increase usage of personal protective gear (individual behaviour change). Based on our observations of so few youth using helmets, which is consistent with a recent historic review on this topic,²⁴ motivating usage is likely going to require a shift in attitude and/or mandating usage with rigorous enforcement to support that behaviour change.

Collapsing over age and examining both the success and severity outcomes of tricks for all youth supports several conclusions (table 4). Flip tricks were less successfully executed and resulted in falls that were more severe. Designing skateparks with features that limit these will likely reduce fall injuries. In contrast, turn tricks were more often successfully executed and the falls were less severe. Thus, designing parks in ways that supported the execution of turn tricks may contribute to fun experiences while limiting risk of severe falls. The category of 'other' types of tricks was often successful; however, when falls occurred they were more severe. Our findings revealed a variety of tricks under 'other' and these were most popular for older skateboarders. A more thorough examination of what features are implicated in the execution of these tricks that pose risk for serious falls is an important next step in order to determine if there are other features that might be avoided to reduce the severity of fall injuries on skateparks.

Limitations and future research directions

Although reliability for child age and sex was excellent, validating these estimates by directly gathering demographic information from youth is recommended. Additionally, as expected our sample was primarily male,⁸ ¹² ¹³ ²⁵ but it would be useful to strategically recruit female skateboarders and assess if their results differ, since there are differences in size and strength of females and males. Finally, this study measured fall severity based on what was observed and the potential for injury. It would be useful to talk directly with skateboarders who have experienced a medically attended injury and assess how these affect their decisions with regard to features they will use and/or tricks they plan to attempt on returning to the skatepark.

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