BJSM Online First, published on January 17, 2013 as 10.1136/bjsports-2012-091439

Prevention of fall-related injuries in 7-year-old to 12-year-old children: a cluster randomised controlled trial

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Received 5 June 2012
Revised 3 December 2012
Accepted 18 December 2012

ABSTRACT

Introduction To counteract the recently observed increase in forearm fractures in children worldwide, an educational programme to improve fall skills was developed. In this 8-week programme children learned basic martial arts falling techniques in their physical education classes. In this study, the effectiveness of this educational programme to improve fall skills was evaluated.

Methods A cluster randomised controlled trial was conducted in 33 primary schools. The intervention group received the educational programme to improve falling skills during their physical education (PE) classes whereas the control group received their regular PE curriculum. At baseline (October 2009) and follow-up (May 2010), a questionnaire was completed by the children about their physical activity behaviours. Furthermore, fall-related injuries were registered continuously during an entire school-year.

Results A total of 36 incident injuries was reported in the intervention group, equalling an injury incidence density (IID) of 0.14 fall-related injuries per 1000 h of physical activity (95% CI 0.09 to 0.18). In contrast, 96 injuries were reported by the control group corresponding to an IID of 0.26 (95% CI 0.21 to 0.32). However, because intracluster correlation was high (ICC=0.46), differences in injury incidence were not statistically significant. When activity level was taken into account, a trend was shown suggesting that the 'falling is a sport' programme was effective in decreasing falling-related injury risk, but only in the least active children.

Discussion and conclusion Although results did not reach significance because of strong clustering effects, a trend was found suggesting that a school-based educational programme to improve falling skills may be more beneficial for the prevention of falling-related injuries in children with low levels of habitual physical activity.

INTRODUCTION

The health benefits of regular participation in sports and physical activity in both children and adults are widely known.[1–3] However, a negative side effect of an active lifestyle is an increase in injury risk. In children, the most costly injury is a forearm fracture.[4] Fractures to the forearm currently account for roughly one-third of the total number of child fractures presented at emergency departments.[5] The most common mechanism of this injury type is fall related, with around 80% of injuries occurring in this fashion.[6] It has been suggested by Parfitt[7] that 'fractures are an inescapable consequence of an appropriate level of physical activity', but what if incidence data suggest that the incidence of forearm fractures has significantly increased over the last 40 years?[5 8]

The literature suggests several causes for the rise in forearm fractures: (1) the rise might be caused by an increase in the number of falls because of increasing physical activity levels[5 8] (2) the risk of a fracture after a fall could be increased because of increasing obesity prevalence.[9] (3) Last, it is suggested that the ability to deal with the forces generated during a fall has declined, because of decreased acquisition of bone mass in children.[8] Which of those mechanisms truly causes the increase in forearm fractures is yet to be determined, and most likely, it is a combination of factors. The bottom line is that we know most forearm fractures are caused by a fall, but also that we cannot prevent a child from falling. However, what we can do is increase their ability to properly react while falling. Therefore, an educational programme was developed based on basic falling techniques derived from martial arts techniques as martial arts techniques have shown to reduce forearm ground reaction force.[10 11]

Because children with low levels of habitual physical activity are more prone to sustain a physical activity-related injury,[12] it was decided to develop the educational programme for use outside the sports setting. Firstly, because little-active children are less likely to participate in sports, and secondly because children partake in a substantial amount of unorganised physical activity.[13] This (non-sport) physical activity is promoted specifically in little-active children through national physical activity programmes. By embedding fall-related injury prevention in regular physical education classes, potentially all children at risk are targeted.[14]

The objective of this study was to evaluate the effectiveness of an educational programme developed to improve fall skills, on fall-related injury risk in 7-year-old to 12-year-old children. Because previous research has shown physical activity-related injury prevention to be more beneficial for little-active children, differences between highly active and little-active children were expected.

METHODS

Design and participants

The effectiveness of the educational programme to improve fall skills was studied in a cluster

To cite: Nauta J, Knol DL, Adriaensens L, *et al. Br J Sports Med* Published Online First: 16 January 2013 doi:10.1136/bjsports-2012-091439

randomised controlled trial (RCT) in 33 Dutch primary schools (3317 children).

Before the start of the present study, a pilot project was undertaken in which fall-related injury prevention clinics were offered to a limited number of primary schools. The goal of the pilot was to ascertain whether schools were interested in participating in fall-related injury prevention, and to test the feasibility of the prevention programme and materials in practice. Interest in these clinics exceeded expectations and 250 schools could not participate. These schools were again contacted to partake in the current cluster RCT.

Schools were eligible for participation if they (1) were a regular primary school, (2) gave regular physical education (PE) classes and (3) were willing to appoint a contact person for the duration of the study. All children in grades 5 through 8 (7–12 years of age) of the participating schools were eligible to partake in the study. Parents of the participating children received a passive, informed consent form which explained the nature and procedures of the study. If either parent or child did not want to participate, they could withdraw from the study at any moment. This study was registered in the Netherlands Trial Register (trial code=2031).

Randomisation to either the control or intervention group was performed after recruitment had finished. At the beginning of the school-year, schools were informed about their group assignment and received corresponding instructions about the study: the intervention group was instructed to carry out the 8-week programme to improve fall skills, whereas the control group continued their regular PE curriculum. Control schools were informed that they would receive the instruction materials the year after follow-up. Participants and researchers were not masked for group allocation.

Sample size

Before recruitment of participating schools, a difference in the incidence of fall-related injuries by 50% between groups after 1 school-year was considered to be clinically relevant. With the incidence of fall-related injuries in Dutch 10-year-olds to –12-year-olds being 4% in 1 year,[13] a total sample of 2511 children was required to detect the intended injury reduction, with a power of 80%, an α of 5% (two-sided) and an assumed dropout rate of 10%. As concise data on the intracluster correlation in relation-to-injury risk between schools are lacking, this could not be accurately adjusted for in the power analysis. As such, we arbitrarily chose to increase the sample size by another 30% to account for potential clustering between schools. This resulted in a final required sample size of 3264 children.

Intervention programme

The fall-related injury prevention programme revolved around martial arts techniques that taught children to distribute the impact energy associated with a fall over a larger contact area and to convert the fall into a rolling motion.[15] In adults, these falling techniques have shown to reduce femoral impact force[15 16] and forearm ground reaction force[10 11] The most important aspect of the lessons was to avoid blocking a fall with extended elbows, so as to reduce forearm impact forces.[10 11 17] Furthermore, children were taught to keep their head from touching the ground and to slap the ground hard with hand to stop the rolling motion.

Exercises were prescribed in an 8-week programme, consisting of weekly 1 h lesson of increasing difficulty. The lessons were to be executed during the regular PE class (figure 1). Teachers were instructed through a written manual, an instruction DVD containing all exercises and instruction cards designed to support the students during the exercises. Teachers were advised on how to implement programme components into their regular PE classes after the initial 8-week programme, in order to provide sustained exposure to the intervention.

Measurements

The primary outcome measure was the number of newly reported fall-related injuries (incidence) in the 8 months after baseline. To obtain all necessary data, two methods of measurement were applied: a physical activity questionnaire (completed by the participating children in October 2009 and May 2010) and a continuous fall-related injury registration. Both questionnaires are described in more detail below and have been used successfully in comparable school-based injury research.[18]

Physical activity questionnaire

At the start (October 2009) and end (May 2010) of the school-year, all children completed a questionnaire in the classroom under supervision of a class room teacher. Teachers were requested to administer the questionnaire after a regular school week. The questionnaire contained questions on age, gender, ethnicity and injuries in the preceding 3 months. In addition, in line with a comparable study by Collard *et al*,[18] questions on the regular weekly frequency and duration of sports and leisure time physical activity were asked. Those questions were adapted from the Adolescent Physical Activity Recall Questionnaire.[19] This questionnaire was validated for use in adolescents and used in previous research in children.[18]

Mean weekly sports and leisure time physical activity exposure was calculated from the baseline and follow-up weekly exposure values, and multiplied by the number of weeks between the completion of the consecutive questionnaires.[18] A correction factor of 0.8 was used in order to account for seasonal variation in physical activity participation throughout the follow-up period. Although chosen arbitrarily, this correction factor is in line with the decrease in physical activity during winter as found in previous studies.[20] The exposure to PE was reported by the (PE) teacher and was multiplied by the number of weeks between baseline and follow-up, taking the regular school holidays into account.

Injury registration

Fall-related injuries were registered by PE teachers on a weekly basis. Children were asked by their teacher whether they had sustained a fall-related injury, and in case of such an event, an injury registration form was completed with the help of the teacher. The injury registration form provided information about the type of injury, location, severity and activity performed at the time the injury occurred (physical education class, sports or outdoor play).

Teachers were instructed to only report fall-related injuries that met one of the criteria defined by van Mechelen *et al*:[21] a child (1) had to stop the current activity; and/or (2) could not (fully) participate in the next planned activity; and/or (3) could not go to school the next day; and/or (4) required medical attention (ie, ranging from first aid to hospitalisation).

Injuries that did not meet one of these criteria, or injuries that were not fall-related, were excluded from analysis.

The severity of each injury was assessed by the reported sporting and/or playing time loss. If the child could play outside or sport the day after the injury had occurred, this was considered a mild injury. In case the child reported not to be able to

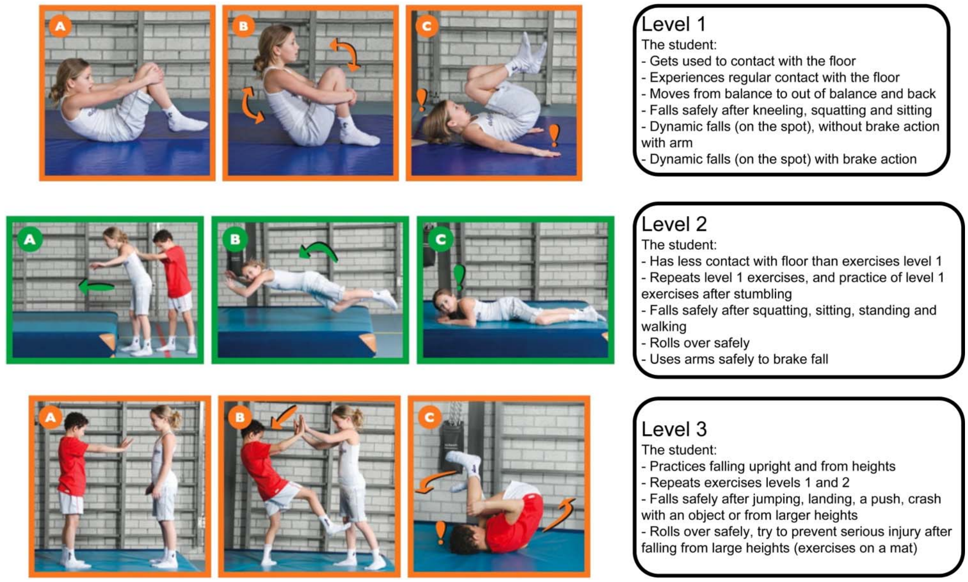

Figure 1 Three examples of exercises in the educational programme. Examples were derived from the educational programme 'Vallen is ook een sport', permission to reprint was granted by the Dutch Consumer Safety Institute

play outside or sport for at least 1 day after the injury had occurred, this was considered a severe injury.

Statistical analysis

Before starting further analysis, baseline variables of the control and the intervention group were analysed for differences by an independent samples t test for continuous variables, and χ^2statistics for categorical variables.

The fall-related injury incidence density (IID) and corresponding 95% CI were calculated for each group separately, as the number of fall-related injuries reported per 1000 h of physical activity exposure.

IID was separately calculated for the high-active and low-active children to detect differences in effect between low-active and high-active children.

Differences (ie, ORs) between the intervention and control group in the probability of injury and the severity of injuries (yes/no) were calculated using a mixed logistic regression model with random intercept. Intracluster correlations (ICC) will be given. A generalised linear mixed model (the Gllamm procedure in Stata V.11.2 (StataCorp, Chicago, Illinois))[22–24] was used for the computations. Several models were applied to the data: model 1) adjusting for cluster effects; model 2) model 1+adjusting for baseline differences; model 3) model 2+(group)×(total minutes of physical activity) interaction term.

RESULTS

Participants

A total of 36 schools were randomly allocated to the control or intervention group. Before the start of the study, one school dropped out because the PE teacher had left the school before the start of the school-year. After the start of the study, one school did not return the children's' baseline questionnaires, and one school was lost to follow-up due to illness of the PE teacher (figure 2). Only the 33 primary schools that completed both baseline and follow-up questionnaires were included in the analysis. In total, 3317 children completed the baseline questionnaires (intervention group: 17 schools, 1397 children, control group: 16 schools, 1920 children).

Baseline characteristics are displayed in table 1. At the start of the study, there were no differences between both groups with respect to age (mean 10.7 years) and gender. Children in the

Figure 2 Flowchart of schools and participants.

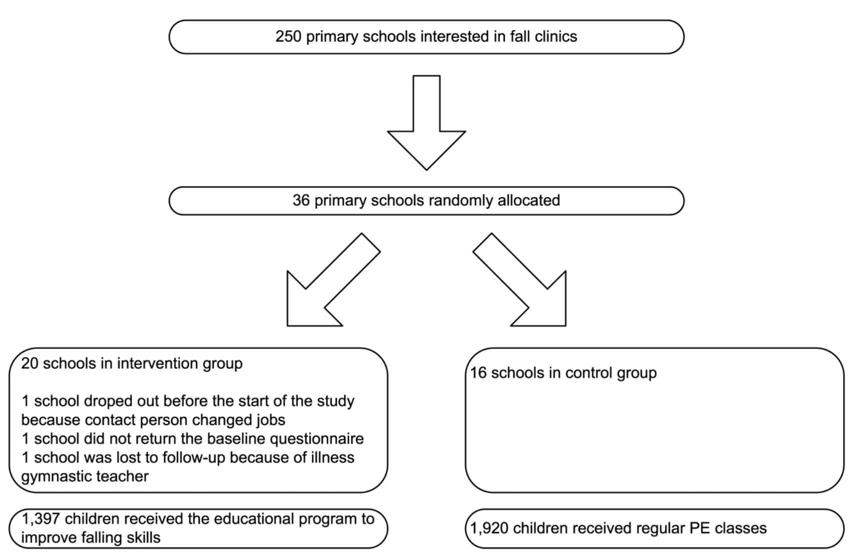

Table 1 Demographics of participants

Characteristics	Intervention group (N=1397)	Control group (N=1920)
Age, mean (±SD) (year)	10.7 (1.3)	10.7 (1.3)
Gender, n (%)		
Boy	714 (51)	972 (51)
Girl	683 (49)	948 (49)
Ethnicity**, n (%)		
Western origin	1108 (79)	1596 (83)
Non-Western origin	237 (17)	268 (14)
Unknown	52 (4)	56 (3)
Habitual physical activity**, mean (±SD) (min/w)	630 (326)	662 (325)
Injuries in 3 months prior to baseline, n (%)		
Wound**	776 (56)	953 (50)
Contusion**	390 (28)	458 (24)
Fracture	46 (3)	43 (2)
Concussion*	52 (4)	46 (2)

* p<0.05.
** p<0.01.

intervention group were significantly: less active during the week (630 min/week SD=326 vs 662 min/week SD=325); more likely to be of a non-Western origin and; more likely to report an injury in the 3 months prior to the baseline measurement.

Fall-related injury incidence

During the follow-up period, a total 206 fall-related injuries were reported by 132 children. A total of 36 injuries was reported in the intervention group, equalling an IID of 0.14 fall-related injuries per 1000 h of physical activity (95% CI 0.09 to 0.18). In contrast, 96 injuries were reported by the control group corresponding to an IID of 0.26 fall-related injuries per 1000 h of physical activity (95% CI 0.21 to 0.32).

Unadjusted logistic regression analyses showed a significant decrease in fall-related injuries in the intervention group (OR 0.50, 95% CI (0.34 to 0.74)) (table 2). However, after adjustment for clustering, no significant differences were found between the intervention and control groups (model 1, OR 0.70, 95% CI (0.18 to 2.71), ICC=0.47). All variables that differed at baseline were included in the model (ie, ethnicity, minutes physical activity and injuries 3 months prior to baseline measurement), but this resulted in minor differences in the results (model 2, OR 0.69, 95% CI (0.18 to 2.63), ICC=0.46).

Table 2 Effectiveness of the educational programme on fall-related injury risk

Model	OR	95% CI	p Value
Unadjusted model	0.50	(0.34 to 0.74)	<0.001
Model 1	0.70	(0.18 to 2.71)	0.603
Adjusted for cluster effects			
Model 2	0.69	(0.18 to 2.63)	0.582
Model 1+ adjusted for: habitual physical activity, previous injuries and ethnicity			
Model 3	0.66	(0.17 to 2.55)	0.548
Model 2+ interaction (participant group X habitual physical activity)			

Table 3 Fall-related injury incidence corrected for 1000 h physical activity

	Injuries per 1000 exposure hours		
	Intervention group	Control group	IDR*
Overall	0.14 (0.09 to 0.18)	0.26 (0.21 to 0.32)	0.52 (0.35 to 0.76)
Injuries per activity group			
Least active group (<639 min/week)	0.16 (0.08 to 0.24)	0.37 (0.27 to 0.48)	0.44 (0.25 to 0.77)
High-active group (>640 min/week)	0.12 (0.07 to 0.17	0.21 (0.15 to 0.26)	0.59 (0.35 to 0.98)

*Incidence density ratio (IDR), expressed as intervention vs control.

Previous research has shown that children who are least active have an increased injury risk,[12] and might benefit more from an injury prevention intervention.[14] This seemed also true for participants in the current study. After categorising all participants according to physical activity into the 'high-active' and 'low-active' group, respectively, incidence density ratios (IDRs) appeared to be larger in the low-active group (IDR 0.44; 95% CI 0.25 to 0.77) than in the most active group (IDR 0.59; 95% CI 0.35 to 0.98, table 3). Based on these findings, an interaction term was included in the logistic regression analysis, resulting in a trend that suggests that the educational programme to improve falling skills was more beneficial for children who were least physically active (table 2, model 3, OR 0.66, 95% CI (0.17 to 2.55), p=0.087 for participant group X habitual physical activity term, ICC=0.46).

Fall-related injury severity

Injury severity was based on the question if a child could participate in any form of physical activity the day after the injury occurred. If not, the injury was considered severe. Otherwise, the injury was considered to be a mild injury. Of the injured children in the intervention group, 83% reported a severe injury, compared to 61% in the control group. Logistic regression analyses revealed that differences between groups were not statistically significant. This did not alter after adjusting for cluster effects and covariates (ie, ethnicity, habitual physical activity and injuries 3 months prior to baseline measurement).

DISCUSSION

The present study is one of the few intervention studies on physical activity-related injuries in children,[25] and to our knowledge, the first to target fall-related injuries in a school-based setting. Unadjusted results showed a reduced number of fall-related injuries in the intervention group, compared to children who did not receive the intervention. After adjustment for clustering, results were not significant. However, when activity level was taken into account, a trend was shown suggesting that the educational programme was effective in decreasing fall-related injury risk only in the least active children.

The latter finding is in line with findings of Collard *et al*[14] who, in a comparable study, reported that their physical activity-related injury prevention programme showed larger effects for those children with low physical activity levels. This is arguably due to the increased injury risk in the low-active group as found in our study, as well as reported by Bloemers *et al*.[12] While injury risk is high owing to reasons yet to be established, preventive effects may be high. This dilutes the overall effect when adjusting the analyses for the clustered design.

Strengths and limitations

This study has, besides strengths, also a few limitations that need to be addressed. These will be described separately for the educational programme, the schools participating in this study and the measurements used.

A major strength of this study was that the intervention targeted all children, including those children who seem to benefit most from fall-related injury prevention (ie, the least active ones). By developing the intervention such that PE teachers can implement the educational programme to improve falling skills into their classes, all children in a specific age category can be reached without exclusion. The effectiveness of the intervention depends heavily on the adherence of the teachers to the programme. Studying such adherence was outside the scope of the current paper, yet in short, teachers reported to have given an average of five out of eight lessons. This gives room for improvement. With some adjustments of the programme to better fit the needs of the PE teachers, this intervention might be more effective. Therefore, although results are modest and non-significant in the present study, a broader implementation of the evaluated intervention could have a substantial Public Health impact.

A strength of the study was that 33 schools were willing to participate. However, although sample size was large, over 3300 children, clinically relevant results failed to reach significance after correcting for clustering (ICC=0.5). Apparently, children were more alike within a school and differed more between schools than initially expected. The high intercluster correlation was underestimated in the power-analysis, resulting in a lack of power to reveal significant differences in the present study. It is uncertain as to whether the recruitment of schools for this study has influenced the intercluster correlation. Participating schools were recruited from a waiting list for fall-related injury prevention clinics. These clinics had received some national press coverage during the school-year 2008–2009. Reasons for schools to register for the clinic are unclear. The fact that participating schools were selected out of the waiting list is, of course, a limitation of this study. This selection might restrict generalisability of the results to those schools that are interested in fall-related prevention.

The measurement methods used are another strength of this study. First of all, effectiveness of the programme was evaluated using the incidence density and severity of injuries. Injury prevention research in children has usually based results on changes in safety knowledge and risk behaviour.[26] This approach seems reasonable, but the history of injury research is littered with studies that have succeeded in improving knowledge and altering attitudes without accompanying changes in injury incidence.[27] For this reason, injury outcomes need to be established to show true intervention effects at a practical level.

The data collection methods, that is, self-reports, used have their advantages as well as disadvantages. For the injury collection, self-report has the advantage that the 'tip-of-the-iceberg' phenomenon[28] does not apply while all injuries have been reported instead of registration of severe injuries via medical channels. A concern with self-reported data might be that events are not recorded or ill-recorded. To counteract the risk of missed injuries during the continuous injury registration, teachers received regular emails to remind them of the importance of the injury registration. Additionally, teachers were instructed to complete the injury forms together with the injured child. For the physical activity data, teachers were instructed to administer the questionnaire after a regular school week. Because children usually have a fixed week schedule, this would help them in recalling the sport and outdoor play during the previous week. The same method of data collection design was previously successfully employed in a study with comparable goals and a comparable design.[18]

CONCLUSIONS

Although results did not reach significance because of strong clustering effects, a trend was found suggesting that a school-based educational programme to improve falling skills can be beneficial for the prevention of injuries associated with a fall. No effects were found regarding the effectiveness of the educational programme on the severity of injuries. The results of the educational programme are nonetheless promising, while children at increased injury risk are suggested to benefit most from this intervention.

> **What are the new findings?**
>
> - Fall-related injury pose a significant burden for primary school-aged children.
> - School-based injury prevention programmes target all children at risk for fall-related injuries.
> - Although results seem weak, from a public health perspective, this minimal invasive intervention to prevent fall-related injuries embedded in physical education classes has great potential.

Acknowledgements We would like to thank Myrthe Bartelink, Mariëtte Geuke and Tessa Könemann for their administrative support, and Yos Lotens and 2Basics for developing the educational programme 'Vallen is ook een sport'.

Funding This study was partially supported financially by Dutch Ministry of Health, Welfare and Sports.

Competing interests None.

Ethics approval The intervention was implemented by the Dutch Consumer Safety Institute. This study was performed alongside this implementation and therefore no ethical approval was obtained. To secure privacy, this study was registered at the Dutch Data Protection Authority.

Provenance and peer review Not commissioned; externally peer reviewed.

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Br J Sports Med published online January 17, 2013
doi: 10.1136/bjsports-2012-091439