Is there a link between children’s motor abilities and unintentional injuries?

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Abstract

Problem: The common view is that clumsy children experience unintentional injury more frequently. Empirical evidence supporting this position is mixed. Method: One hundred 6- and 8-year-olds completed a battery of nine tasks designed to assess motor ability. Mothers completed a lifetime injury history measure about their children and families completed a 2-week injury diary assessing frequency and severity of daily injuries. Results: Internal reliability for the motor ability battery was good. Correlations between motor ability measures and injury risk were nonsignificant and near zero. Discussion: Motor ability does not appear to be directly related to injury risk. Possible explanations include: (a) coordinated and clumsy children engage in hazardous activities with differing frequency; or (b) other individual difference factors may interact with motor ability to explain children’s injury risk. Impact on industry: Children’s motor abilities do not appear to be directly linked to rate of unintentional injury, but instead may influence risk for injury in conjunction with other factors. Results could have implications to the engineering of children’s toys and playground equipment and to the design of appropriate supervision strategies for children engaging in potentially dangerous activities.

Keywords: Children; Injury; Safety; Motor abilities; Clumsiness

1. Introduction

Unintentional injuries are the leading cause of childhood mortality in the United States (National Safety Council, 2001), causing the death of more children than all other diseases combined (Rodriguez & Brown, 1990) and the loss of over 2 million years of life annually (Routh, 1997). Despite such alarming statistics, behavioral predictors of childhood injuries remain poorly understood. Recently, researchers have begun to identify and examine individual differences that may lead certain children to have a higher rate of injuries than others. To date, this research on individual differences has focused primarily on temperamental (Pulkkinen, 1995; Schwebel & Plumert, 1999), cognitive (Matheny, 1980; Plumert, 1995), social (Christensen & Morrone, 1997; Peterson & Brown, 1994), and attitudinal/attributional (Morrone, 1997; Morrone & Rennie, 1998) factors that may play a role in injury risk.

One area of child development that has been largely overlooked as a predictor of childhood injury is motor development. Despite the common view that clumsy children injure themselves more frequently, few published studies have carefully considered how individual differences in motor ability may lead some children to have increased risk of injury. Available literature examining children’s motor development and possible links to unintentional injury risk is mixed (see Matheny, 1988; Gratz, 1992 for brief reviews). One early study found children with more accidents at school were rated as having poorer motor skills by physical education teachers (Angle, 1975). A second found the opposite: boys rated with high athletic proficiency by their mothers and girls rated with high athletic proficiency by their teachers were found to have higher accident rates (Manheimer & Mellinger, 1967). In that study, corresponding ratings for girls by mothers and for boys by teachers yielded nonsignificant differences.
The most extensive previous work on children’s motor ability and injuries followed a cohort of nearly 1,000 children in Dunedin, New Zealand longitudinally from birth until age 7 (Langley, Silva, & Williams, 1980a; Langley, Silva, & Williams, 1980b). Children’s motor skills were assessed at age 3 with the Bayley Scales and at age 5 with the McCarthy Motor Scales. Neither measure was related to injury history from birth to age 5 (Langley et al., 1980a). At age 7, a second, more comprehensive assessment was conducted with a subset of 822 children using the Basic Motor Ability Test (BMAT; Langley et al., 1980b). The BMAT includes a battery of nine subtests divided into two factors. The first factor encompasses a long jump, an agility run, target throwing, push-ups, and the face-down-to-standing task and was defined as “large muscle strength and skill.” It was positively related to children’s injury history from birth to age 7: those children with more injuries were stronger and more athletically skilled. The second factor of the BMAT, which assessed agility and fine motor skill, was unrelated to injury history.

Thus, results of previous research are mixed on whether unintentional injury history is correlated with motor ability. Both positive and negative relations have been reported, and there are several indications that there may not be any significant relation at all between the two variables. The most comprehensive study to date is limited because the significant finding was a positive correlation between injury and well-practiced motor abilities—primarily muscle strength—rather than motor coordination, balance, and agility (Langley et al., 1980b). This finding is contrary to the common perspective that clumsy children—those with poor coordination and balance—are injured most frequently.

The present study revisits the question of whether motor ability is related to unintentional injuries. Two manipulations were included to test the relation between motor ability and unintentional injury more thoroughly than previous work. First, a nine-task motor ability battery was developed to encompass not just motor strength and well-practiced motor skills, but also balance, coordination, and agility. Second, the researchers measured not only major injuries requiring professional medical attention, but also asked families to complete a daily injury diary to assess quantity and severity of children’s minor injuries over a 2-week period.

2. Methods

2.1. Participants

Fifty 6-year-old children and fifty 8-year-old children participated in the study (51 boys, 49 girls). The 8-year-old group had a mean age of 8 years, 6 months (range = 8 years, 1 month to 9 years, 0 month) and included 27 boys and 23 girls. The 6-year-olds had a mean age of 6 years, 7 months (range = 5 years, 10 months to 7 years, 1 month) and included 24 boys and 26 girls. Most participants were Caucasian and from middle to upper socioeconomic status backgrounds.

2.2. Design and procedure

The laboratory session was divided into two segments. The first was part of a separate investigation and is not reported here. During the second segment, children completed a battery of nine tasks to assess motor ability. Tasks were divided into three categories: (a) balancing ability (walking on a balance beam, walking with a block balanced on the head, and balancing on one foot with eyes closed); (b) hand– and foot–eye coordination in a speeded situation (stringing beads, retrieving balls to a basket with hands, and retrieving balls to a basket with feet); (c) hand— and foot–eye coordination in a non-speeded situation (pouring water into a series of containers, tossing beanbags into a basket, and catching a ball swung in a pendulum motion).

Each child performed each of the nine motor tasks twice consecutively. Those tasks requiring later coding were recorded via a camcorder through a one-way mirror. Each task is described in detail below; tasks were presented to all participants in a consistent order that matches the order of presentation below.

2.2.1. Motor ability measures

2.2.1.1. Balance beam walking. Children attempted to walk across an 8-ft-long-by-1.5-in.-wide (2.44 m × 3.81 cm) beam placed 4 in. (10.16 cm) off the ground. Distance traveled on the beam was recorded.

2.2.1.2. Balancing block on head. The experimenter balanced a small wooden block on each child’s head. Children were permitted to adjust the block if they felt it was balanced poorly and then were asked to walk beside a wall, up to 12 ft (3.66 m), or until the block fell off their head. Children were not allowed to touch the wall. The distance traveled before the block fell was recorded.

2.2.1.3. Balancing on one foot. Children stood comfortably in the middle of a room, closed their eyes, and were instructed to hold the foot of their choice in front of them while balancing on the second foot. The time children maintained balance without hopping or placing their second foot on the ground was recorded.

2.2.1.4. Bead stringing. Children stood beside a small table, were given a bowl of 15 wooden beads and a string with a knot tied on one end, and were instructed to place the beads on the string as quickly as possible. The time required to string the beads was recorded.
2.2.1.5. Ball retrieving by hand. Nine tennis balls were spread around a medium-sized rectangular room. The balls were placed uniformly for all children, at distances ranging from 38 to 120.5 in. (96.52–306.07 cm) from a box placed on the floor in the center of the room. Children retrieved balls one at a time, in any order, and returned them to the box. The time from leaving a uniform starting position until the final ball was placed into the box was recorded.

2.2.1.6. Ball retrieving by foot. Four tennis balls were spread around the same room. Again, balls were placed uniformly for all children, at distances ranging from 53 to 120.5 in. (134.62–306.07 cm) from a box placed on the floor. In this case, the box had a sloped entry on one side, and a small lip at the top of the entry to retain balls inside the box. Children were permitted to use only their feet to push the balls into the box. On the rare occasion when a child attempted to use his or her hands, the experimenter redirected the child and replaced the ball where it had been. Again, children retrieved only one ball at a time, in any order, and the time from leaving a uniform starting position until the final ball was placed into the box was recorded.

2.2.1.7. Water pouring. Children stood beside a small table and were given a measuring cup filled with 500 ml of water. Children were successively given six other containers and poured the original water from one container into the next. Four containers had wide openings and two had small openings approximately the size of plastic milk jugs [1.5 in. (3.81 cm) diameter]. Children were cautioned that time was unimportant in this task; focusing on avoiding spills was more critical. The last container children poured water into was the same measuring cup used at the beginning, allowing the experimenter to record the amount of water left and compute the quantity of spilled water.

2.2.1.8. Beanbag tossing. Children stood in a small box marked on the floor and were given a beanbag. A large bucket with a 10-in. (25.4 cm) diameter opening was placed 6 ft, 10 in. (2.11 m) from the child. Children made seven attempts to throw the beanbag into the bucket. The experimenter recorded the number successfully tossed.

2.2.1.9. Ball catching. The experimenter stood across the room from the child and held a wooden ball with a 2-in. (5.08 cm) diameter attached to the ceiling by a string. The experimenter held the ball along the wall 52 in. (132.08 cm) above the floor, counted to three, and released the ball, so it would pendulum toward the child sitting in a chair against the opposite wall. The ball approached most children toward their upper chest. Children were instructed to catch the ball as it approached, using one hand, and without grabbing the string to corral the ball. Eight attempts were made, and the experimenter recorded the number of successful catches.

2.2.2. Injury risk measures

While children completed the laboratory battery, their mothers completed several questionnaires. The only questionnaire pertinent to the present study was the Unintentional Injury Questionnaire (UIQ), which asked parents to report all lifetime injuries children experienced that required a visit to a doctor or hospital. Details concerning the UIQ are available elsewhere (Plumert, 1995).

After completing the laboratory session, families were invited to complete a daily injury diary to record all injuries that the children incurred over the subsequent 14 days. Eighty-five (85%) of the families agreed to complete diaries and return them. Details about diary administration are available elsewhere (Schwebel, Binder, & Plumert, 2002), but briefly, parents recorded on a daily basis the circumstances of each injury, minor or major, that children incurred. Administration allowed for forgotten days (22% of families in this study skipped one or more days but still provided complete 14-day diaries); diaries were completed only during warm parts of the year, when children tend to play outdoors. To deal with possible misinterpretations concerning what constituted an “injury” (Peterson, Brown, Bartelstone, & Kern, 1996), families were instructed to record anything they considered injurious to the children in the diary and coders later reviewed the recorded injuries and removed any injuries that did not include either tissue damage or pain on the part of the child.

After diaries were returned, research assistants coded the severity of each injury on a 4-point scale. The most minor injuries—those requiring no treatment—were scored 1. Minor injuries requiring home first aid were scored 2; those that were more major, but still did not require professional medical treatment were scored 3. Unlike injuries scoring 2, injuries coded with a severity of 3 generally required multiple types of treatment (e.g., washing, ointment, and bandages) or required substantial amounts of time for treatment (e.g., cleansing and bandaging for more than 5 min). Finally, those injuries requiring professional medical treatment were scored 4. To assure reliability, injury severity was coded independently by two research assistants on a randomly selected 16% of the sample; \( \kappa = 1.00 \).

Since increased participation in athletics by children with good coordination and balance could cause increased opportunity for injury, coders also rated whether injuries occurred during organized athletic activities (with a coach and team present, during practice or competition), during unorganized athletic activities (supervised or unsupervised, at schools, neighborhoods, parks, etc.), or during any other nonathletic activities. Coding on a randomly
means (and standard deviations) of motor measures

<table>
<thead>
<tr>
<th>Task</th>
<th>Total (N = 100)</th>
<th>Boys (n = 51)</th>
<th>Girls (n = 49)</th>
<th>Age 6 (n = 50)</th>
<th>Age 8 (n = 50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance beam walking (in.)</td>
<td>66.04 (27.78)</td>
<td>63.74 (28.71)</td>
<td>68.39 (26.89)</td>
<td>60.42 (28.42)</td>
<td>71.55 (26.27)*</td>
</tr>
<tr>
<td>Balancing block on head (in.)</td>
<td>81.92 (50.26)</td>
<td>70.63 (50.28)</td>
<td>93.43 (48.06)**</td>
<td>62.40 (48.01)</td>
<td>101.06 (45.17)**</td>
</tr>
<tr>
<td>Balancing on one foot (s)</td>
<td>7.33 (6.23)</td>
<td>6.84 (6.52)</td>
<td>7.85 (5.94)</td>
<td>4.70 (2.88)</td>
<td>9.97 (7.49)**</td>
</tr>
<tr>
<td>Bead stringing (s)</td>
<td>60.24 (17.43)</td>
<td>65.14 (19.52)</td>
<td>55.14 (13.33)**</td>
<td>68.85 (18.70)</td>
<td>51.63 (10.63)**</td>
</tr>
<tr>
<td>Ball retrieving by hand (s)</td>
<td>29.77 (5.54)</td>
<td>30.18 (6.33)</td>
<td>29.35 (4.61)</td>
<td>31.83 (4.74)</td>
<td>27.71 (5.57)**</td>
</tr>
<tr>
<td>Ball retrieving by foot (s)</td>
<td>78.83 (43.23)</td>
<td>70.90 (40.68)</td>
<td>87.08 (44.66)</td>
<td>99.53 (48.98)</td>
<td>58.12 (22.43)**</td>
</tr>
<tr>
<td>Water pouring (ml)</td>
<td>320.86 (96.76)</td>
<td>309.75 (98.10)</td>
<td>332.19 (95.04)</td>
<td>265.71 (92.64)</td>
<td>374.90 (65.56)**</td>
</tr>
<tr>
<td>Bead stringing (% made)</td>
<td>36 (17)</td>
<td>40 (17)</td>
<td>33 (17)*</td>
<td>29 (16)</td>
<td>44 (16)**</td>
</tr>
<tr>
<td>Ball catching (% caught)</td>
<td>49 (31)</td>
<td>57 (31)</td>
<td>41 (29)**</td>
<td>29 (26)</td>
<td>68 (23)**</td>
</tr>
</tbody>
</table>

Means (and standard deviations) of injury measures

<table>
<thead>
<tr>
<th>Task</th>
<th>Total (N = 100)</th>
<th>Boys (n = 51)</th>
<th>Girls (n = 49)</th>
<th>Age 6 (n = 50)</th>
<th>Age 8 (n = 50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medical injuries</td>
<td>1.31 (1.44)</td>
<td>1.49 (1.51)</td>
<td>1.12 (1.35)</td>
<td>1.42 (1.43)</td>
<td>1.20 (1.46)</td>
</tr>
<tr>
<td>Diary injuries</td>
<td>5.70 (3.55)</td>
<td>6.67 (3.77)</td>
<td>4.81 (3.13)*</td>
<td>5.82 (3.76)</td>
<td>5.57 (3.35)</td>
</tr>
<tr>
<td>Diary injuries, not organized athletics</td>
<td>5.34 (3.47)</td>
<td>6.05 (3.84)</td>
<td>4.66 (2.96)*</td>
<td>5.49 (3.66)</td>
<td>5.17 (3.29)</td>
</tr>
<tr>
<td>Diary injuries, not athletics</td>
<td>4.73 (3.32)</td>
<td>5.24 (3.52)</td>
<td>4.25 (3.07)</td>
<td>5.11 (3.48)</td>
<td>4.32 (3.12)</td>
</tr>
<tr>
<td>Diary injury severity</td>
<td>1.30 (0.34)</td>
<td>1.29 (0.29)</td>
<td>1.30 (0.38)</td>
<td>1.33 (0.29)</td>
<td>1.26 (0.39)</td>
</tr>
</tbody>
</table>

* p < .05 on ANOVA comparing groups by age or gender.

3. Results

3.1. Descriptive data

On all motor tasks, children’s scores on the two trials correlated highly (mean r = .52, range = .23–.78), so a single score was created for each task by averaging the two trials. Table 1 presents the mean scores for each of the nine tasks. Scores for each of the nine motor tasks were entered into separate age (2) × gender (2) ANOVAs to test for age and gender differences. Consistent with developmental expectations, 8-year-olds performed better than 6-year-olds on all nine motor ability tasks (See Table 1). Girls performed better than boys on two tasks, the Balancing block on the Head and the Bead stringing tasks, while boys performed better than girls on two tasks, the Beanbag tossing and Ball catching tasks (Thomas and French, 1985).

Table 2 reports average scores on the injury measures and the results of age (2) × gender (2) ANOVAs comparing age and gender groups. Boys had slightly higher injury rates on most measures. There were no age differences on the injury measures. The nonathletic and nonorganized athletic injury measures from the diary also had significant age-by-gender interaction effects, with 6-year-old boys and 8-year-old girls having the highest injury rates on both measures.

3.2. Intercorrelations between motor tasks

Each motor task was standardized and transformed if needed so that high scores indicated greater motor skills. All tasks were intercorrelated, with age and gender partialled (see Table 3). Intercorrelations were moderate and positive (average interitem correlation = .19, range = -.08 to .51; Cronbach’s α = .82). Within the three categories of motor tasks (balancing ability, speeded hand– and foot–eye coordination, and non-speeded hand– and foot–eye coordination), average intercorrelations were r = .15, r = .28, and r = .14, respectively. With the exception of the three speeded coordination tasks, children performed as similarly across areas of motor development as they did within areas, so further analyses were conducted with an aggregated single measure of all nine motor ability tasks. An age (2) × gender (2) ANOVA yielded a significant effect of age, with 8-year-olds (M = .14, S.D. = .31) scoring significantly higher than 6-year-olds (M = −.14, S.D. = .26).

3.3. Correlations between motor abilities and injuries

To test the primary hypothesis of the study, the aggregated motor score was correlated with the injury measures (See Table 4). With age and gender partialled, none of the correlations reached significance. The two...
strongest correlations were each $r(77) = .17$, between motor ability and the number of diary injuries and between motor ability and the number of non-organized athletic diary injuries.

Given these nonsignificant correlations, further correlations were conducted with the individual motor tasks. Table 4 presents the data for all nine motor tasks correlated with the three injury measures. Just 2 of the 45 correlations reached significance at the $p < .05$ level, under chance expectations for the number of correlations computed. Those two correlations were in the opposite direction: one found that greater motor skill (on the ball catch task) was related to increased injury risk and the other found that lesser motor skill (on the beanbag toss task) was related to increased injury risk. Using the more conservative $p < .01$ level, or with a Bonferroni correction to adjust for the number of analyses, no correlations reached significance. Likewise, correlations were nonsignificant and near zero using the three original groupings of motor tasks into balance, speeded coordination, and non-speeded coordination tasks.

4. Discussion

Results suggest motor ability is not related to children’s injury risk. The nine-task battery of children’s motor ability demonstrated good inter-task reliability and age and gender differences on the motor tasks were in expected directions, together suggesting the motor battery was a valid measure of motor skill. Correlations between the motor battery and five measures of injury risk—including measures of major lifetime injuries requiring medical attention and more minor injuries reported in a 14-day injury diary—were not significant and near zero, even after controlling for age, gender, and injuries incurred while participating in athletics. Correlations between the individual motor tasks that comprised the nine-task battery and the measures of injury risk also failed to demonstrate a link between injury risk and motor ability.

It is possible that one or both of the constructs of interest—injuries and motor ability—were measured poorly in the sample. However, given the consistent lack of significant correlations across facets of the measures, two
alternative hypotheses are offered to explain why motor ability may not be closely related to children’s injury risk. The first relates to opportunity for injury. Coordinated children may participate more frequently in potentially injurious activities such as organized sports; riding of bicycles, roller skates, and skateboards; and climbing of trees and playground equipment, with greater frequency than clumsy children. This increased opportunity for injury among coordinated children could bias the results of direct correlations between coordination and injury (Langley et al., 1980b; Manheimer & Mellinger, 1967).

A preliminary attempt to test this hypothesis was conducted by correlating injury rate with children’s scores on the Experiences and Activities Checklist (EAC) and suggested increased activity was unrelated to increased injury risk (Langley et al., 1980b). However, the EAC is designed to measure experience, a construct that is theoretically different than behavior. In other words, the EAC is a measure that asks children to report what activities they have ever attempted—it does not assess the frequency of participation in various activities. In the present study, this hypothesis was also examined peripherally by correlating motor abilities with nonathletic injuries reported in children’s diaries. Again, results did not support the hypothesis: even with athletic injuries removed, correlations between motor skills and injuries were nonsignificant. Nonetheless, further tests of this hypothesis are warranted.

A second explanation for the lack of a correlation between motor abilities and children’s injuries is that other individual difference factors may interact with motor ability in explaining children’s injuries. For example, children’s overestimation of physical ability has previously been linked to injury risk: children who estimate they can reach and step further than they actually can have a higher injury rate than children who are more accurate at estimating their physical abilities (Plumert, 1995; Plumert & Schwebel, 1997). Moreover, impulsive and highly active children are more likely to overestimate their abilities than nonimpulsive counterparts (Plumert & Schwebel, 1997; Schwebel & Plumert, 1999). This suggests that the confluence of multiple behavioral factors places children at increased risk for injury. The findings of the present investigation suggest that motor ability by itself is not predictive of injury risk. However, this does not preclude the possibility that a combination of temperamental characteristics, ability overestimation, and motor ability may play a role in injury risk. Children who are both highly impulsive and poorly coordinated may be particularly poor at estimating their physical abilities, leading to increased risk of unintentional injury. Further research is necessary to determine whether motor ability contributes to injury risk in conjunction with other behavioral factors.

In closing, this study adds to a small but growing body of literature suggesting that motor skill is not directly related to injury risk. Rather, motor skill may play a role in injury risk in conjunction with other factors such as exposure to hazards and temperament. That said, two potential limitations of this study should be mentioned. The first is an issue that continues to plague the injury field: how should one quantify injuries, inherently subjective and oftentimes ambiguous events? This study used two methods: major injuries that required visits to emergency rooms and quantity and severity of minor injuries reported in a 14-day diary. Each, though widely used and consistently correlated to other risk factors for injury, has limitations. The major injury measure is subject to parental biases in seeking and receiving professional medical attention and in recalling those events. Minor injury measures are also subject to parental and child reporting and recalling biases. Our choice to include all diary injuries that involved either pain or tissue damage was highly inclusive and therefore subject to great individual differences; note, however, that alternatives have other weaknesses (Peterson et al., 1996; Schwebel et al., 2002). Second, a relatively small cross-sectional sample was used to test the hypothesis. Future research should consider larger samples that are followed longitudinally to test more carefully the relation between children’s motor coordination and risk for unintentional injury.

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