Developmental Gender Differences for Overhand Throwing in Aboriginal Australian Children

Jerry R. Thomas, Jacqueline A. Alderson, Katherine T. Thomas, Amity C. Campbell, and Bruce C. Elliott

In a review of 46 meta-analyses of gender differences, overhand throwing had the largest gender difference favoring boys (ES > 3.0). Expectations for gender-specific performances may be less pronounced in female Australian Aboriginals, because historical accounts state they threw for defense and hunting. Overhand throwing velocities and kinematics were recorded in 30 female and male Aboriginal Australian children 6–10 years old. Results indicated the Aboriginal girls and boys were more similar in horizontal ball velocities than U.S. girls and boys. Throwing kinematics between girls and boys were also more similar in Australian Aboriginals than U.S. children. Aboriginal girls threw with greater velocities than U.S., German, Japanese, and Thai girls, while the boys were similar across cultures.

Key words: biomechanics, cultural influences, overhand throwing, skill development

There is substantial evidence that boys throw farther, with more velocity (Atwater, 1979; Thomas & French, 1985), and more effective biomechanical techniques than girls (Atwater, 1979; Thomas & Marzke, 1992). However, the differences in throwing performance may have both biological and cultural components. Many girls involved in sports, such as softball and cricket, have demonstrated highly advanced throwing patterns; however, girls and young women typically have shown less skilled throwing performances and less advanced kinematic patterns than boys and men (Thomas, Gallagher, & Thomas, 2001; Yan, Hinrichs, Payne, & Thomas, 2000; Yan, Payne, & Thomas, 2000). Thus, gender differences in throwing are greater and evident at a younger age when compared with other motor performance tasks (Thomas & French, 1985).

Girls and boys have consistently demonstrated significant differences in overhand throwing as early as 4 years of age (Thomas & French, 1985). In fact, the effect size difference at 4 years of age is three times as great (1.5 vs. 0.5) as any other motor tasks evaluated and continues to increase through adolescence to an effect size above 3.0 (Thomas & French, 1985). Overhand throwing was the largest gender difference among the 46 meta-analyses on gender differences reported by Hyde (2005). Gender differences of this magnitude suggest minimal overlap in the throwing score distributions between typical girls and boys (Thomas & French, 1985), even when corrected for physical characteristics such as size, muscle, and skeletal robustness (Nelson, Thomas, Nelson, & Abraham, 1986; Watson & Kimura, 1991).

Gender Differences in Overhand Throwing Performance: Distance and Velocity

In a longitudinal study (summarized in Table 1) Halver-son, Roberton, and Langendorfer (1982) reported average throwing velocities for U.S. boys and girls from kindergarten, first, second, and seventh grades. While the change rates in throwing velocity were similar between boys and girls (10–12% per year), girls in kindergarten
threw 73.9% of the velocity thrown by boys, and by seventh grade it had dropped to 72.1%. Runion, Robertson, and Langendorfer (2003) reported similar results in their study of 13-year-old boys and girls from Ohio.

Haubenstricker and Seefeldt (1986) reported that differences in throwing distance between boys and girls increased (particularly postpuberty) since 1960. Their data showed that, the average distance thrown by girls 14–18 years of age prior to 1960 was about 21.5 m and about 46.2 m for boys. However, for data collected after 1960, the average distance thrown by girls 14–18 remained relatively constant, only increasing to 23.0 m, while boys increased to 58.5 m. The prepuberty differences were similar before and after 1960; however, at 8 years of age girls still threw approximately 60% as far as boys. Nelson, et al. (1986) reported differences favoring boys at 6 years of age, with girls throwing only 57% of the distance boys threw. They suggested that biological characteristics (e.g., body fat, joint robustness) accounted for about 10% of the difference in throwing distance between boys and girls.

In a cross-cultural comparison, Ehl, Robertson, and Langendorfer (2005) reported throwing velocity differences for 13-year-old German children (boys and girls) and compared that information with earlier data on U.S. children. U.S. boys threw with a velocity of 23.2 m/s (SD = 4.86), and German boys threw 21.31 m/s (SD = 1.53). U.S. girls threw at a velocity of 16.29 m/s (SD = 2.27), and German girls threw 14.23 m/s (SD = 1.07). U.S. girls threw at 70.2% of the velocity of U.S. boys, whereas German girls threw at 66.8% of the velocity of German boys.

In a study of three international cultures, Sakurai, Chentanez, and Elliott (1998) reported differences in throwing distance between 420 girls and boys 7, 9, and 11 years of age in Australia, Japan, and Thailand. Boys and girls increased throwing distance in similar patterns to those reported in the United States; however, the Australian and Japanese children threw further than the children from Thailand. These differences may be due to overhand throwing sports, such as cricket and baseball, being played in Australia and Japan, respectively. The percent of distance girls threw compared to boys was similar to data reported in previous studies (51–69%). Across all cultures that were compared, the velocity for boys from 5–13 years of age ranged from 11.9 to 23.9 m/s and for girls from 8.8 to 17.2 m/s. The percent of velocity when dividing girls’ velocity by boys’ ranged from 51 to 73.9%.

### Differences in the Components of Overhand Throwing for Children

In two studies using high-speed video, Stodden, Langendorfer, Fleisig, and Andrews (2006a, b) evaluated the kinematics of overhand throwing in 34 boys and 15 girls ranging in age from 3 to 15 years (M = 9.8 years, SD = 3.3). However, the basis for comparison was not gender. Rather the throwing pattern was evaluated using the component rating scales developed by Robertson and Halverson (1984). Throwing characteristics were sorted by developmental level (component rating). For the various components, Level 3 (most developmentally advanced movement mechanics) was nearly all boys:

- Humerus action (26 of 26 were boys),
- Forearm action (23 of 23 were boys),
- Step length (26 of 28 were boys), and
- Trunk rotation (23 of 23 were boys).

Conversely, girls were most often at Level 1. For example, girls were rated at the lowest level 27 times across four components, but boys were at the lowest level only 5 times. When children in the study were grouped based on the three levels of throwing mechanics, most girls were in Levels 1 and 2, and most boys were in Levels 3 and 4 (some components have only three levels and others have four).

For step length and trunk components (Stodden et al., 2006a), Level 4 had the longest step length, with differences occurring in Levels 3 and 2. Step length was a significant predictor of horizontal ball velocity, accounting for 69.3% of the variance. For trunk action component, Levels 3, 2, and 1 were different from each other for pelvic angular velocity, maximum upper torso angular velocity, maximum pelvic linear velocity, maximum upper torso linear velocity, and trunk tilt at release. Ball velocities were also different at all levels, as previously reported.

In evaluating arm contributions (Stodden et al., 2006b), children classed as Level 3 (most developmentally advanced arm mechanics) had significantly higher ball velocities than those classified as Levels 2 and 1. Of the six biomechanical characteristics used for the arm/shoulder, only shoulder abduction at ball release was significantly different among all three levels, although no long axis rotation for the upper arm was measured. Children rated as Level 3 had more advanced kinematic characteristics than those rated as Levels 1 and 2. The Level 1 and 2 children were not significantly different from each other. Children classified as more developmentally advanced in biomechanics were nearly all boys, with girls generally classified into the lower levels.

### Table 1. Data (m/s) summary for previous throwing study by Halverson, Robertson, and Langendorfer (1982)

<table>
<thead>
<tr>
<th>Grade level</th>
<th>Boys (n = 22)</th>
<th>Girls (n = 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Kindergarten</td>
<td>11.95</td>
<td>2.4</td>
</tr>
<tr>
<td>First grade</td>
<td>13.62</td>
<td>2.5</td>
</tr>
<tr>
<td>Second grade</td>
<td>15.27</td>
<td>2.6</td>
</tr>
<tr>
<td>Seventh grade</td>
<td>23.86</td>
<td>3.1</td>
</tr>
</tbody>
</table>

*Note. M = mean; SD = standard deviation.*
Throwing in Aboriginal Australian Children

Australian Aborigines provided an opportunity to study overhand throwing in children, especially given the cultural expectation for Aboriginal Australian girls to throw. Australian Aborigines never became food producers. Instead, they remained hunter gatherers, which required the ability to throw weapons and/or hunting instruments (Clarke, 2003).

Given the previous explanation, Aboriginal girls may be expected to be more successful in both technique and ball velocity of overhand throwing than girls from other cultures. The historical separation of the Aboriginal Australian people from Western and Asian cultures may have insulated the Australian Aborigines from factors that might have had an impact on gender differences. Aboriginal girls’ throwing may more closely resemble the throwing skills of Aboriginal boys. Such a similarity would be a clear contrast to the observed differences in throwing for girls and boys from other cultures.

Purpose of Study

This study evaluated the kinematics and horizontal ball velocities (and their reliability estimates) in overhand throwing of 6-, 8-, and 10-year-old Aboriginal Australian girls and boys, a group for which there is no previous kinematic data. We also compared effect sizes from gender differences in Aboriginal children with gender differences in children from other cultures. We evaluated the following hypotheses:

1. Girls and boys were expected to show typical developmental differences of improved horizontal ball velocities and movement kinematics at increased age levels;
2. Aboriginal Australian girls were expected to have similar horizontal ball velocities and throwing kinematics when compared with Aboriginal Australian boys of the same age; thus, the gender differences were predicted to be relatively small;
3. Aboriginal Australian boys were predicted to be similar to U.S. boys, while Aboriginal girls were predicted to exceed U.S. girls in horizontal ball velocities and movement kinematics.

In addition a principal components analysis was used to group Aboriginal Australian children based on horizontal ball velocity (rather than gender). Key throwing kinematics were expected to discriminate among the groups of children.

Method

Participants

Mooditj Community College pupils (an Aboriginal Australian school on the northern edge of the Perth metropolitan area) were recruited for this study. The sample (N = 30) consisted of 15 boys (5 at each of three age levels) and 15 girls (5 at each of three age levels) of elementary school age who were placed into one of six gender-age matched groups (see Table 2 for descriptive data). The Ethics and Human Research Committee of the University of Western Australia approved the investigation. The school principal and parents/guardians gave consent for their children to participate, and the children gave their verbal consent. Participants were transported from their school to the Biomechanics Laboratory at the University of Western Australia for data collection.

Procedures

Participants’ standard anthropometric measures of height and mass were recorded. Children were asked if they played on organized sports using overhand throwing (cricket or baseball). None reported playing on such teams. Following three warm-up trials, each participant completed a minimum of three maximal effort overhand throws at a large indoor goal (2.14 m high x 3.66 m wide)

Table 2. Demographic participant information

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (years)</th>
<th>Age (years) M</th>
<th>SD</th>
<th>Height (cm) M</th>
<th>SD</th>
<th>Mass (kg) M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Girls</td>
<td>6</td>
<td>6.6</td>
<td>0.5</td>
<td>118.8</td>
<td>7.2</td>
<td>23.4</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>8.4</td>
<td>0.4</td>
<td>132.6</td>
<td>2.5</td>
<td>29.3</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>9.9</td>
<td>0.3</td>
<td>134.1</td>
<td>8.1</td>
<td>33.1</td>
<td>4.5</td>
</tr>
<tr>
<td>Boys</td>
<td>6</td>
<td>6.1</td>
<td>0.2</td>
<td>112.8</td>
<td>4.7</td>
<td>21.5</td>
<td>1.3</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>7.9</td>
<td>0.5</td>
<td>124.2</td>
<td>4.7</td>
<td>23.0</td>
<td>3.2</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>9.6</td>
<td>0.3</td>
<td>135.9</td>
<td>8.1</td>
<td>31.8</td>
<td>9.1</td>
</tr>
<tr>
<td>Combined</td>
<td>6</td>
<td>6.4</td>
<td>0.4</td>
<td>115.4</td>
<td>6.4</td>
<td>22.3</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>8.1</td>
<td>0.5</td>
<td>128.4</td>
<td>5.7</td>
<td>28.0</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>9.8</td>
<td>0.3</td>
<td>135.1</td>
<td>7.6</td>
<td>30.7</td>
<td>7.7</td>
</tr>
</tbody>
</table>

Note. M = mean; SD = standard deviation.
located 5 m in front of the release position. Participants were instructed to throw the tennis ball as hard as possible (e.g., with maximum velocity), with no further instructions or coaching provided. The first author observed all practice and recorded throws relative to common throwing characteristics (vigorous movement, long step, ball speed) to be certain that participants threw with maximal effort. Motion capture data of the participant and ball were recorded at 250 Hz with a 12-camera Vicon motion analysis system (Oxford Metrics Ltd., Oxford, UK). A customized University of Western Australia biomechanical model and marker set were used (based on the design of Lloyd, Alderson, & Elliott, 2000). The marker set consisted of 38 retroreflective markers, 10 mm in diameter, fixed to the child’s skin by adhesive double-sided nonallergenic tape (see Figure 1). The tennis ball was defined with two retroreflective markers affixed to opposing sides. Prior to data analysis, participants performed a static trial to establish local anatomical coordinate systems at each joint.

Data Reduction and Modeling

Each trial was visually inspected to eliminate random marker movement incongruent with the motion being performed. The raw motion capture data were smoothed at 18 Hz, determined via residual analysis, using a recursive digital Butterworth filter. The model used, which followed the standards outlined by the International Society of Biomechanics (Wu & Cavanagh, 1995), was written using Body Builder software (Oxford Metrics Ltd., Oxford, UK) and allowed for three-dimensional (3D) kinematic data determination. The model outputs 3D motion for all degrees of freedom at the wrist, elbow, shoulder, trunk, and pelvis segments. Segment motion was described relative to the laboratory coordinate system or relative to another segment (joint angle). Joint angles were referenced to the anatomical position, with the determination of each axis displacement calculated in an ordered series of rotations, namely: flexion/extension, adduction/abduction, and internal/external rotation. Uniquely, the shoulder angles were determined by polar angle decomposition, the current method for representing shoulder joint kinematics in throwing (Doorenbosch, Harlaar, & Veeger, 2003).

Dependent variables were selected based on previous research on overhand throwing of more expert performers (Matsuo, Escamilla, Fleisig, Barrentine, & Andrews, 2001). Horizontal ball velocity was calculated; kinematic variables of interest included stride length, peak upper torso separation (rotation) angle (upper torso segment relative to the pelvis segment); elbow flexion at release (forearm segment relative to the upper arm segment); and shoulder abduction, horizontal adduction, and external rotation (upper arm segment relative to the thorax segment). In addition, corresponding peak angular velocities were calculated for shoulder abduction, horizontal shoulder adduction, internal shoulder rotation, elbow extension, and upper torso closing velocity (shoulders to hips). The 3D ball trajectory was used to determine the forward horizontal velocity via standard differentiation procedures. Data were analyzed from the start of the throwing motion (initial pelvis forward rotation) through ball release to 1 s following release. The data were temporally normalized to 100 points for between-participant comparisons. Kinematic averages for each child at discrete time points (e.g., immediately following ball release) as well as minimum and maximum values for the throwing motion were calculated for three trials; then the three trials were averaged to form each dependent variable.

Statistical Analysis

Data were visually analyzed for errant data points prior to statistical analysis. All analyses were performed in SPSS (version 12) following screening for normality and outliers. Reliability of kinematic variables and horizontal ball velocity between trials by gender and age were evaluated using intraclass correlation (ICC) estimates. Gender and age group differences for horizontal ball velocity, height, mass, and kinematic variables of interest were examined using a 2 x 3 factorial analysis of variance (2 genders x 3 age groups) with Scheffe post hoc follow-up. Children were then grouped on horizontal ball velocity using a principal components analysis. Using these groupings, a discriminant analysis was conducted with step...
length and the six kinematic variables. For all statistical analyses, the criterion alpha level was set to .05.

Based on our sample size, power was estimated using an effect size of 0.75 (most gender comparisons for throwing are greater than this value), 0.99 for pairwise comparisons, 0.97 for comparing three groups, and 0.72 for interaction comparisons. We corrected alpha for multiple tests using the Bonferroni procedure (alpha divided by the number of comparisons). We also report effect sizes (Hedges & Olkin, 1985, p. 76) to guide the interpretation of meaningful findings as well as to compare data from Aboriginal Australian children with that from U.S. children.

Results

Overall Data

Data for one 6-year-old girl and one 10-year-old girl were not available for analysis, thus, reducing the sample size to 28 (13 girls and 15 boys). One other 6-year-old girl had outlying data points for four kinematic variables. However, further analysis revealed no error in data collection or entry, and her original values were used for analysis.

Anthropometric Variables

A significant age effect was observed for height, $F(2, 22) = 39.36$, $p < .001$, and mass, $F(2, 22) = 4.83$, $p = .022$. The 10-year-olds were taller and weighed more than the 6-year-olds. The 8-year-olds were also taller than the 6-year-olds (see Table 2). No differences in anthropometric variables were observed between genders or for the interaction.

Reliability

The results suggested that Aboriginal children demonstrated good reliability for horizontal ball velocity (7 of 9 age/gender groups > .90, and the other 2 groups > .82; see Table 3), stride length (2 of 3 age groups > .86), and the kinematic variables (with the exception of shoulder abduction angle at release and peak internal rotation velocity). Overall, 28 of 42 (67%) reliability estimates were in the acceptable range (> .8). Given the children’s ages and small sample sizes, this seems to suggest relatively reliable performance on most aspects of the task. While previous authors (e.g., Halverson, Roberton, & Langendorfer, 1982) reported reliability estimates for ball velocity, this is the first paper to report reliability estimates for kinematic variables related to overhand throwing in children.

Horizontal Ball Velocity

Significant age and gender effects were observed for peak horizontal ball velocity. On average, the boys threw 3.36 m/s faster than the girls, $F(1, 22) = 13.63$, $p < .001$, (see Table 4), and the 10-year-olds threw 2.94 m/s faster than the 6-year-olds, $F(2, 22) = 4.71$, $p = .022$ (see Table 5). The difference between average peak horizontal ball velocity for 8-year-olds and 6-year-olds was 2.45 m/s and approached significance, $p = .053$; there was no interaction between age and gender for horizontal ball velocity, $p > .10$. The effect sizes for differences between boys and girls within age groups were 0.73, 2.40, and 1.81 for the 6-, 8-, and 10-year-olds, respectively. Overall, the horizontal ball velocity for girls was 78.3% of that for boys (data for 13 girls and 15 boys were used in this calculation).

Kinematic Variables

There were significant gender effects for peak upper torso separation angle, $F(1, 22) = 5.01$, $p = .035$; shoulder horizontal adduction angle at ball release, $F(1, 22) = 4.44$, $p = .041$; peak shoulder external rotation angle during throw preparation, $F(1, 22) = 7.38$, $p = .014$; and elbow

<table>
<thead>
<tr>
<th>Table 4. Dependent variables with significant gender effects</th>
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<tbody>
<tr>
<td>Dependent variable</td>
</tr>
<tr>
<td>Ball velocity (m/s)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Peak rotation</td>
</tr>
<tr>
<td>separation velocity (°/s)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Shoulder horizontal</td>
</tr>
<tr>
<td>adduction at release (°)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Peak shoulder</td>
</tr>
<tr>
<td>external rotation (°)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Elbow flexion</td>
</tr>
<tr>
<td>at release (°)</td>
</tr>
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<td></td>
</tr>
</tbody>
</table>

Note. $M = \text{mean}; SD = \text{standard deviation}$.
flexion angle at ball release, $F(1, 22) = 12.20, p < .001$ (see Table 4). Boys showed greater peak shoulder external rotation angle during the preparatory phase (see Figure 2), and girls showed greater upper torso separation angle, shoulder horizontal adduction angle, and elbow flexion angle at release (see Figures 3 and 4). Due to the large standard deviation in elbow flexion angle at release, the ensemble curves did not properly display the gender effect. Therefore, no ensemble curve is shown for elbow flexion angle at release. There were no differences in kinematic variables between age groups. However, a significant interaction, $F(2, 22) = 3.51, p < .05$, was found for shoulder abduction angle at release. Figure 4 indicates that peak shoulder abduction decreased for the 8- to 10-year-old boys, and increased for the 8- to 10-year-old girls.

**Discriminating Among Throwing Velocity Groups**

As previously noted, Stodden et al. (2006a, 2006b) grouped children by the qualitative form of their throwing prior to kinematic analysis. We used age and gender as our grouping variable, but another nonarbitrary way of grouping is horizontal ball velocity. We did a principle components analysis on horizontal ball velocity that resulted in three groups: (a) fastest horizontal ball velocity (FHBV)—horizontal throwing velocities from 16.1 to 20.5 m/s ($M = 18.1, SD = 1.4$); (b) moderate horizontal ball velocity (MHBV)—horizontal throwing velocities from 12.0 to 14.7 m/s ($M = 13.4, SD = 0.8$); and (c) slowest horizontal ball velocity (SHBV)—horizontal throwing velocities from 8.6 to 10.9 m/s ($M = 10.2, SD = 0.9$). The FHBV group was composed of 7 boys, all 8 or 10 years of age. The MHBV group was composed of 7 boys and 8 girls spread across the three age groups of 6, 8, or 10 years of age. The SHBV group comprised one 6-year-old boy and 5 girls, 6, 8, or 10 years of age. Of course, because the groupings were done on horizontal ball velocity, they were significantly different on this variable, $F(2, 25) = 106.5, p < .0001, R^2 = .89$. A Scheffe post hoc test of the means revealed all three groups differed from each other.

A forward stepping discriminant analysis was used to compare the three groups on stride length, peak upper torso separation (rotation) angle, elbow flexion at release, shoulder abduction, horizontal adduction, and external rotation. Stride length was the best discriminator, $F(2, 25) = 17.5, p < .001$. Peak upper torso separation angle was entered on Step 2, $F(4, 48) = 11.4, p < .0001$, and elbow flexion at release was entered at the third and final step, $F(6, 46) = 10.5, p < .001$. Using the three variables in a linear composite to classify participants, 6 of 7 (86%) of the FHBV group were correctly classified, 14 of 15 (93%) of the MHBV group were correctly classified, and 5 of 6 (83%) of the SHBV group were correctly classified. Figure 6 shows group means with 95% confidence intervals for the three variables.

**Discussion**

The purpose of this study was to determine the differences in kinematics and horizontal ball velocities (and

![Figure 2](https://example.com/figure2.png)

**Figure 2.** Mean shoulder external rotation angle from commencement of forward throwing movement to ball release (axial rotation remained negative to avoid shoulder misrepresentation).
their reliability estimates) between age groups and gender in Aboriginal Australian children. In addition, we grouped children by horizontal ball velocity (using a principle components analysis) and then used stride length and kine-

**Figure 3.** Mean upper torso separation angle from start of forward throwing movement to ball release. Zero indicates shoulder and pelvic alignment; negatives show more rotation in shoulder alignment than pelvic alignment. Note the higher rate of change in girls.

**Figure 4.** Mean shoulder horizontal adduction angle from commencement of forward throwing movement to ball release.

**Figure 5.** Mean elbow flexion angle at ball release (+ or – 95% confidence interval) across age groups and gender.
matic variables to discriminate among the horizontal ball velocity groups. By using these data to make comparisons with other cultural groups, we could evaluate whether differences among girls and boys from Aboriginal Australian, U.S., and other cultures were similar or different, with respect to the throwing variables analyzed.

In accordance with previous research, a significant age and gender effect was observed for horizontal ball velocity.

**Figure 6.** Velocity groupings; 1 = SHBV (slowest horizontal ball velocity), 2 = MHBV (moderate horizontal ball velocity), 3 = FHBV (fastest horizontal ball velocity) for stride length (a), shoulder-pelvis flexion (b), and elbow flexion (c) with 95% confidence intervals.
velocity (Thomas & French, 1985). On average, boys threw faster than girls, and horizontal ball velocity increased with age for both girls and boys. A previous meta-analysis suggested the mean effect sizes for gender differences in horizontal ball velocity among American children were approximately 1.25 for 6-year-olds, 2.25 for 8-year-olds, and 3.25 for 10-year-olds (Thomas & French, 1985). The effect sizes for gender differences among Aboriginal Australian children in this study were 0.73, 2.40, and 1.81 for the 6-, 8-, and 10-year-olds, respectively. Thus, differences between boys and girls were lower in 6- and 10-year-old Aboriginal Australian children when compared with U.S. children and about the same for 8-year-olds in each culture.

Data on U.S. children (Halverson, Robertson, & Langendorfer, 1982) have shown average throwing velocities of 11.9 m/s (SD = 2.4) and 15.3 m/s (SD = 2.6) for 6- and 7-year-old boys, which are similar to the 12.7 m/s (SD = 1.5) and 16.7 m/s (SD = 2.01) for 6- and 8-year-old Aboriginal Australian boys. However, U.S. girls, at 6 and 7 years of age threw at 8.8 m/s (SD = 2.6) and 10.6 m/s (SD = 2.7) respectively, compared with 6- and 8-year-old Aboriginal Australian girls, who threw at 11.3 m/s (2.6) and 12.3 m/s (SD = 1.7), respectively. While throwing velocity for U.S. and Aboriginal boys slightly favored the Aboriginal Australian boys at ages 6 (ES = 0.38) and 7 versus 8 years (ES = 0.61), the Aboriginal Australian girls threw at substantially higher ball velocities than U.S. girls (ES = 0.95 for 6-year-olds and ES = 1.22 for 7 vs. 8-year-olds). Australian Aboriginal girls threw at 78.3% of the horizontal ball velocity of Aboriginal Australian boys, the highest percent reported across Australian (non-Aboriginal), German, Japanese, Thai, and U.S. cultures. None of the Aboriginal Australian girls and boys in our sample reported participation in organized cricket or baseball teams. However, the ball velocities and large effect sizes suggested that Aboriginal Australian girls threw substantially better than U.S. girls. This finding supported our notion that, historically, Australian Aboriginal girls and women, just as boys and men in other cultures, place greater value on the ability to throw.

As would be expected, we observed a significant age effect for height and mass. The 8- and 10-year-olds were taller than the 6-year-olds, and the 10-year-olds weighed more than the 6-year-olds. As no biomechanical variables were found to have an age effect, the differences between age groups in horizontal ball velocity may have been due at least partially to size (height and weight) and strength rather than improved throwing skill.

We observed significant gender effects for biomechanical variables, including peak upper torso separation velocity, shoulder horizontal adduction at ball release, peak shoulder external rotation, and elbow flexion at ball release. The peak upper torso separation velocity (really deseparation velocity, as shoulders were closing on the hips) was greater for girls than boys. Even in Aboriginal Australian girls and boys, these variables favored the boys. Typically, skilled throwers demonstrate a lag effect in which the humerus is horizontally adducted relative to the trunk during acceleration (Stodden et al., 2006b). In this study, girls had less peak shoulder external rotation and more horizontal adduction at release, suggesting that they did not demonstrate as much of a lag effect as the boys. Boys threw with a more extended arm at ball release (smaller flexion angle) than girls. Other variables being equal, a more extended arm produces a longer radius of rotation, or lever arm, during the throw. For a given angular velocity, a longer radius of rotation would correspond to greater linear velocity at the end of the lever arm.

We also used a nonarbitrary grouping based on horizontal ball velocity, which resulted in all boys being in the group with the fastest horizontal ball velocity while 5 of 6 in the slowest horizontal ball velocity group were girls. The middle grouping was a balance between girls and boys. These groupings, representing skill outcomes in throwing, demonstrated three critical variables that successfully classified participants: stride length, peak upper torso separation angle, and elbow flexion at release. These results were similar to those reported by Stodden et al (2006a, b) when using overhand throwing components to classify children into groups. While these results had some gender bias toward boys for throwing success, they clearly showed that many girls could throw as effectively and efficiently as boys.

The differences in throwing mechanics and ball velocities were less in Aboriginal Australian boys and girls than that observed in other groups of children. The Aboriginal Australian boys demonstrated velocities similar to several samples of U.S. boys. This suggests that the Aboriginal Australian girls are more like their male counterparts in overhand throwing than girls from other cultural groups. It may be reasonable to suggest that during the relatively short period of 200 years of European settlement impacting the Australian indigenous culture, nature and nurture influences on throwing may have been less pronounced than that found in other cultures (i.e., Germany, Japan, Thailand, and the United States; e.g., Young, 2009).

References


**Note**

1. The wrist joint center was defined as the midpoint between the radial and styloid processes. The shoulder joint center was the intersecting point between a line from the anterior to posterior shoulder markers and a perpendicular line dropped from a marker placed on the acromion process. The elbow epicondyles were identified using the pointer method of joint center identification (Besier, Sturmietsk, Alderson, & Lloyd, 2003). The elbow joint centers were referenced to local reference frames during dynamic trials to create the dynamic anatomical joint centers.

**Authors’ Notes**

This research was supported by a fellowship and visiting professor status granted to the first author from the Raine Foundation at the University of Western Australia as well as a Faculty Development Leave to the first and third authors from Iowa State University. Thanks to Tim Derrick, Brent Edwards, and Stacey Meardon, Department of Kinesiology, Iowa State University, for their assistance with this project. Thanks to the children, parents, teachers, and educational leaders at Mooditj Community College for their participation and support of this study. Please address correspondence concerning this article to Jerry R. Thomas, Dean, College of Education, University of North Texas, Denton, TX 76203.

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