THROWING PATTERNS OF OLDER ADULTS: A FOLLOW-UP INVESTIGATION*

KATHLEEN WILLIAMS
University of North Carolina at Greensboro

KATHLEEN HAYWOOD
University of Missouri-St. Louis

ANN VANSANT
Temple University

ABSTRACT

Previous investigations of the movement patterns of older adults have focused on functional movements. Performance declines have been reported with increasing age. Many investigations, however, do not require older adults to perform maximal, force-producing actions. Smaller declines might be observed if older adults made a maximal effort. This investigation examined changes in a maximal skill—the overarm throw for force. Active, older adults were videotaped as they threw tennis balls. Thirteen people were filmed for two consecutive years. Gender and age differences were examined for movement patterns, ball velocity, and selected kinematic measures. Participants threw using patterns and velocities generally observed in children in middle elementary-school years. This result suggested there was a decline in this force production skill. Some older adults regressed in the movement patterns they used over the two years of testing. Older males threw faster, using more advanced movement patterns than older females.

Investigations of movement patterns used by older adults traditionally have focused on functional movements, like walking [1-3] or rising from a supine position [4, 5]. The results of many of these studies suggest gradual declines in

*Partial funding for this research was provided to the first author by a Research Council Grant-in-Aid, Graduate School, University of North Carolina at Greensboro. Portions of this investigation were presented at the Motor Development Research Consortium, Greensboro, NC, October 1989.

motor performance in older adults. At least two models are hypothesized to explain the cause of this pattern of change [6]. One suggests that change is gradual and inevitable, resulting in the onset of a disease state when certain, threshold levels of neural decay are reached. The other hypothesizes that decline is not continuous and linear; rather, a high level of function is maintained until a specific catastrophe is encountered. It is the presence of a disease state that results in observed declines. Researchers subscribing to this latter model suggest that linear declines often characterize motor performances of older adults because healthy and unhealthy older participants are combined in most investigations.

Related to these competing hypotheses, an additional "cause" for the declines that we observe should be examined. It may be that older participants are less likely to go "all out" in their performances of motor skills. Instead, older participants may choose to go slower or more cautiously than their younger counterparts when they are given the option. It may be possible for them to perform at speeds comparable to those observed in younger participants [7]; they simply choose to go slower or use less than maximal force. Few investigations have examined this possibility. In fact, many of the tasks examined in investigations of older adults are performed only at a preferred or most comfortable speed [1]. Investigations where maximal speed or force is a constraint usually involve simple movements (e.g., reaction time) of a single limb or digit [8].

One purpose of this investigation was to examine performances of older adults as they executed a movement skill requiring maximal force—the overarm throw. Would healthy, older adults be able to generate the same amount of force (indicated by velocity) as younger participants? The overarm throw was selected for study since it is a movement skill requiring multi-segmental coordination. Body segments move through an extensive range of motion with precise timing control to result in a forceful throw. In addition, qualitative (movement pattern) assessment of the overarm throw has an extensive validation history [9-11]. Differences in throwing velocity could be related to the use of more or less mechanically efficient movement patterns.

At this time little is known about the patterns of movement used by older adults performing any fundamental or sport-specific motor skills. To our knowledge only our earlier study described older adults' performances of a fundamental motor pattern. That investigation also examined the overarm throw for force in active, older adults [12]. We found that these adults typically used moderately advanced movement patterns. Additionally, there was a tendency for performers who reported more experience in throwing or striking skills (like softball or racquet sports) to use more advanced patterns than those with less experience.

Other questions about the performance of fundamental motor skills have not been asked in relation to older adults. For example, it often is assumed that regression will occur in performances of motor skills as we age; there is little evidence, however, documenting specific declines in these fundamental motor skills. Second, gender differences are observed in the performance of many motor
skills by young adults. It is not clear whether these same differences occur in older adults. Third, if older adults do perform differently than younger adults, the cause of these changes is of interest. Do changes in functional range of motion or balance result in declines in performance, perhaps through a reorganization of the movement pattern?

The present investigation extended our original study of the overarm throw in several ways. First, we were unable to test for gender differences in the initial investigation; there was a disproportionate number of women (16 women, 5 men) in the original sample, making it impossible to examine the data for gender differences. Large gender differences typically are found in studies of younger adults performing the overarm throw [13]. In the present study data were collected from additional male participants. Second, longitudinal evidence is required to determine if participants' performances actually declined or changed in any way with advancing age. These data represent the second year of testing for many of the participants. Finally, in the initial investigation, diminished range of motion and more tenuous balance were hypothesized as reasons for the failure to find performers using advanced movement patterns. Data were collected in order to investigate the relationship between general limitations in balance, range of motion, and throwing performance.

METHODS

Participants

Twenty-four active, older adults, between sixty-three and seventy-eight years of age, from the St. Louis, Missouri area participated in this study. There were fifteen women (mean age 70.93 years; SD = 3.86) and nine men (mean age 71.40 years; SD = 4.50). These adults were participants in the Active Adult Program at the University of Missouri-St. Louis.

The Overarm Throw

Roberton [9] hypothesized developmental sequences for the overarm throw, dividing body actions into segmental movement components (see Table 1). A movement component describes the action of part of the body that changes at a rate different from other body segments [14]. Sequences for each component comprising the overarm throw were validated cross-sectionally and longitudinally using samples of normal [9, 10, 15, 16] and handicapped [17] children and adolescents. With minor modifications Roberton found that movement components for the trunk, humerus, and forearm actions consistently met intransitivity and universality stage criteria proposed in early investigations [10]; nearly all the individuals studied appeared to go through the sequences in a fixed order. Additionally, participants in each of these investigations could be assessed using
Table 1. Developmental Sequences for Movement Components of the Overarm Throw for Force

<table>
<thead>
<tr>
<th>Component</th>
<th>Level 1</th>
<th>Level 2</th>
<th>Level 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk Action Component</td>
<td>No trunk action or forward backward action.</td>
<td>Upper trunk rotation or trunk &quot;block&quot; rotation.</td>
<td>Differentiated rotation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Contralateral foot action, long step.</td>
</tr>
</tbody>
</table>

*Note: Modified from Robertson and Halverson [14]. For complete description of categories, see Robertson and Halverson [14].*

existent categories. No new or different actions occurred, demonstrating that Roberton's categories were comprehensive [10, 17]. The leg action component was found to adhere to stage criteria less consistently, however.

**Movement Task and Instrumentation**

A sagittal view of the adults was videotaped from approximately 9.15 m, using a Panasonic video camcorder (Model PV 330D). The camcorder was equipped with a high speed, 1/1000 s shutter and recorded movement at approximately thirty fields per second. Videotaping took place outdoors on a large, open field. Each adult performed a minimum of five throws for maximum force.

**Data Reduction**

Preliminary data reduction took two forms. The first phase involved classifying trials according to their developmental level using the categories hypothesized and validated (Table 1) by Roberton [14]. Trained observers viewed the trials
using a videodeck (Panasonic Model AG 6300) that enabled them to slow the speed of the action, as well as to view movements field by field.

Before categorizing all the trials, an objectivity criterion of 85 percent exact agreement was established. Both intra- and inter-rater objectivity were examined. One trial for each participant was selected for this phase (a total of 24 trials). Test trials were viewed and analyzed independently; a single rater re-viewed the same trials one month later. There was exact agreement at or above the 85 percent criterion for all movement components. For intra-rater agreement, objectivity levels were 100 percent for the trunk action, 96 percent for the foot action component, and 92 percent for the forearm and humerus actions. Inter-rater exact agreement was 100 percent for trunk and foot actions, 96 percent for humerus actions, and 88 percent for forearm actions. Because high levels of agreement were reached, the remaining trials were reduced by a single investigator.

This was the second year of data collection [12] for thirteen of the elderly participants (10 women, 3 men). Only categorizations of the movement components were available from the first year's data. Comparisons were made between the movement characteristics demonstrated by these individuals for the two years.

In the second phase of data analysis, videotapes were digitized using a video/computer motion analysis system (Peak Performance Technologies, Inc., Englewood, Colorado) to obtain horizontal and vertical coordinates for ball, foot, hip, and shoulder positions throughout the throwing action. A measure of horizontal ball velocity was derived from the two frames immediately following ball release. The trial with the fastest horizontal ball velocity was selected for each participant for additional analysis.

A group of kinematic measures, hypothesized to be related to functional range of motion and balance, were analyzed. The amount of backward movement (relative to the thrower's center of gravity) in preparation for the throw and the forward action following ball release were hypothesized to represent the willingness of participants to move the center of mass outside their base of support. The extent of the movement outside the base of support was taken as an indication of dynamic balance and the participants' ability to apply force over distance. The overall translation of the center of mass, as represented by the linear movement of the hip, was used as a global measure of the range of active movement. Stride length was used as an indication of the active range of motion at the hip. These measures were determined for each participant's fastest velocity trial.

While rotation of the shoulders and pelvis certainly contribute to the action occurring throughout the overarm throw, only the linear component of each measure was examined in this investigation. The extent of linear translation of the hip (same side as throwing arm) was taken as a first approximation of total movement during the throwing action. Translation of the center of mass during the course of the throw was determined by finding the difference between two points: the hip position at the point where the trunk rotated to its most extreme "windup"
position was compared to the location of the hip at the point farthest forward following ball release (Figure 1). Initial and final hip positions also were compared with the position of the front (support) foot to estimate the movement of the center of mass (hip) outside the base of support. Initial hip position, relative to the support (front) foot, was used as a measure of backward movement in preparation for the throw. Both of these measures were constructed by determining the distance between the heel and an imaginary line dropped from the hip, perpendicular to the surface. The final hip position represented movement in front of the base of support following ball release. Stride length was the distance between the front and back foot, following initial foot plant, in preparation to throw. These measures were normalized for the standing height of each participant and are, therefore, reported as percentages.

Chi square tests were applied to categorizations of each movement component to test for gender differences. Gender differences for the kinematic variables were examined using a one-way multivariate analysis of variance. Stepwise regression was used to determine the relationship between the kinematic measures of balance and range of motion and ball velocity.

Figure 1. Schematic of selected kinematic variables measured for this investigation: (a) hip translation, (b) backward movement in preparation for throw, (c) forward movement following release, (d) stride length. All measures were normalized in relation to the participant's standing height. Throwing action moves from left to right.
RESULTS

A total of 131 trials were available for analysis of the movement components of the throwers. Eighty-four trials were performed by women, and forty-seven were performed by male participants. All trials, for all participants, were used to construct frequency distributions for each movement component [18]. For outcome measures (ball velocity, stride length, hip translation, etc.) the trial with the fastest horizontal ball velocity was used for analysis. Digitized data were not available for one male participant.

Movement Components

Four movement components were examined in this investigation (see Table 1): trunk, humerus, forearm, and foot actions (Figure 2). For the trunk action, all 131 trials were placed at level 2 (block rotation). For the humerus, 48.1 percent of the trials (63) were placed at level 1 (humerus oblique); 40.5 percent (53 trials) were placed at level 2 (humerus aligned, but independent); and 11.4 percent of the trials (15) were categorized at developmental level 3 (humerus lags). For the forearm, all trials were placed at levels 1 (no forearm lag) or 2 (forearm lag): 51.9 percent (68) of the trials were categorized as level 1; 48.1 percent (63) of the trials were placed at level 2. For the foot action, no trials were categorized at the least advanced developmental step, level 1 (no step). Nearly all trials were placed at level 3 (contralateral, short step: 92.4 percent, 121 trials). Five trials each (3.8%) were classified at levels 2 (ipsilateral step) and 4 (contralateral, long step).

Gender differences — Significant gender differences were found for the forearm and humerus actions ($\chi^2 = 34.56$ and $\chi^2 = 33.17$, respectively, $p < .001$). Women tended to demonstrate less developmentally advanced actions for both movement components. For the humerus, women were categorized primarily at level 1 (59.5% of their trials), with the remaining trials at level 2 (40.5%). Fewer of the men’s trials were placed at level 1 (27.7%); most of their trials were categorized as level 2 (40.4%) and level 3 (31.9%). The forearm action used by women tended to be placed at level 1 (72.3%), while the actions used by men were categorized most often at level 2 (83%). No individual demonstrated level 3 for the forearm action.

No gender differences were found for trunk or foot actions ($p > .05$). There was no variation in trunk action across participants or trials. Nearly all trials were placed at level 3 of the foot actions of both males and females (89.3% for women; 97.9% for the men).

There have been many investigations of age- and gender-related differences in the overarm throw for force among young children and adolescents. One of these investigations examined longitudinal change between kindergarten and seventh grade [15]. Halverson and her colleagues reported changes in the movement patterns the participants used as well as in the velocity of their forceful throws. It
Figure 2. Percentages of occurrence for each developmental level of humerus (top), forearm (middle), and foot (bottom) action components for all participants. All participants demonstrated level 2 of trunk action across all trials. See Table 1 for descriptions of levels within each movement component.
is instructive to compare the performance of the older adults tested in this study with the performances of these younger participants. Because gender differences were found in only the forearm and humerus of the older adults, only these components will be examined.

For the forearm action (Figure 3), the older women tested in this investigation performed at lower developmental levels than the seventh-grade women tested by Halverson et al. [15]. By seventh grade the majority of trials were categorized at level 2 for the younger participants. In contrast, most older women were classified at level 1. While a small percentage of the seventh-grade women's trials was categorized at level 3, none of the older women demonstrated the most advanced pattern. The older men we tested were more similar to the seventh-grade men. Most of the older men's and seventh graders' trials were categorized at level 2 of the forearm action. In contrast, however, none of the older men's trials were placed at level 3, while nearly half of the seventh graders' trials were categorized at that most advanced level.

Findings were similar for humerus action (Figure 4). Nearly 60 percent of the older women's trials were placed at level 1; only 12 percent of the seventh-grade women's trials were categorized at the lowest level. The remaining trials for the older women were categorized at level 2; none fell into the most advanced level. In contrast, level 2 occurred modally for the seventh-grade women. Further, nearly 30 percent of their trials were placed at level 3. For the older males, trials were distributed over all three developmental levels. Approximately 25 percent of their trials were placed at level 1, 40 percent at level 2, and the remaining trials at level 3. In contrast, most of the seventh-grade men's trials were classified at either level 2 or 3; over 80 percent of their trials were placed at level 3 for the humerus action.

Longitudinal changes — Thirteen participants were tested for two consecutive years (10 women, 3 men). Modal categories for each movement component were compared between the two years. Nine of the participants demonstrated changes in at least one movement component. For two of these individuals, changes occurred in two components. Change was observed in only a single component for the other seven throwers. Most individuals changed within the humerus and foot action components. Four participants demonstrated changes in the humerus across the two years: the movement patterns of three regressed from level 2 to level 1; the remaining advanced from level 2 to level 3. Five individuals changed their foot actions: three regressed from level 4 to level 3; two advanced. One participant changed from level 3 to level 4; the other changed from level 1 to level 3. There were two changes in forearm actions: one participant regressed from level 2 to level 1, while another changed from level 1 to level 2. No changes occurred in the trunk action.

These changes occurred in the face of little additional practice on the part of these older adults. The results from the first year of this investigation [12] demonstrated that most of the participants had had little practice using an overarm
Figure 3. Age and gender differences in percentages of occurrence of developmental levels of the forearm. Age differences for female (top) and male (bottom) participants are shown. Age groups are kindergarten (K), first (1st), second (2nd) and seventh (7th) grades, and older adults (OA). Data for age groups K-7th grade were provided by Mary Ann Roberton, Motor Development and Child Study Laboratory, University of Wisconsin-Madison.
Figure 4. Age and gender differences in percentages of occurrence of developmental levels of the humerus. Age differences for female (top) and male (bottom) participants are shown. Age groups are kindergarten (K), first (1st), second (2nd) and seventh (7th) grades, and older adults (OA). Data for age groups K-7th grade were provided by Mary Ann Roberton, Motor Development and Child Study Laboratory, University of Wisconsin-Madison.
throwing pattern in several decades. Informal conversations with the adults suggested that they had little practice from year one to year two.

**Throwing Velocity and Kinematic Measures**

Throwing velocity was examined to determine whether the “typical” pattern of gender differences (favoring men) might be found among these older throwers. In addition, categorizations for movement components were used to predict throwing velocity. Finally, kinematic variables designed to assess the range of movement and the dynamic balance of these adults were examined.

Gender differences in the five kinematic variables (backward and forward movement, stride length, hip translation, and horizontal velocity) were analyzed using a one-way multivariate analysis of variance. Overall gender differences were found as a result of the omnibus test (Hotelling’s T: $F_{1,6}=4.21$, $p = .0124$). Follow-up one way analyses of variance showed that this overall finding was primarily the result of gender differences in throwing velocity ($F_{1,20}=14.51$, $p = .0011$). Consistent with investigations involving participants, the men in this study threw faster than the women (men’s $m = 54.87$ ft/s, $16.73$ m/s vs. women’s $m = 39.05$ ft/s, $11.91$ m/s). No significant differences were found for the other four variables ($p > .05$ for hip translation, forward and backward movement, and stride length).

Velocity data for our older adults again were compared with the Halverson et al. longitudinal data [15]. These older adults threw more slowly than the seventh graders tested by Halverson and colleagues (Table 2). In fact, the older adults used speeds more comparable to velocities that might be demonstrated by middle elementary-school children. Halverson et al. [15] reported constant “longitudinal units of change” of around 5 feet/second/year for seventh-grade girls and 5.6

<table>
<thead>
<tr>
<th>Table 2. Means and Standard Deviations for Ball Velocities—Kindergarten through Seventh Grade and Older Adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age/Grade</td>
</tr>
<tr>
<td>Sex</td>
</tr>
<tr>
<td>Males</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Females</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

*Note: Data were provided by Mary Ann Roberton, Motor Development and Child Study Laboratory, University of Wisconsin-Madison.*

$^a$Horizontal ball velocities are in feet/second.

$^b$Standard deviations are in parentheses.
feet/second/year for seventh-grade boys. Using these units for comparison suggests that our older adults were throwing at speeds comparable to third-grade children.

Finally, the kinematic variables were examined more closely in order to discover any general relationship they might have to throwing velocity. We reasoned that more forceful throws would be related to longer strides and greater translation or displacement of the hip; individuals moving through a larger range of motion should throw a ball more forcefully. Stepwise regression was used on the four kinematic variables to predict ball velocity. Only the total translation of the hip entered this equation, accounting for 45.5 percent of the variance. None of the other kinematic variables contributed significantly to the velocity of the ball at release.

DISCUSSION

In general, the results of this investigation indicated that some older adults regressed in the movement patterns they use to throw over a one-year period. In addition, older men performed the overarm throw for force using more advanced movement patterns and faster velocities than older women. Older men and women performed at lower levels than those reported for adolescents. There were no gender differences among older throwers for selected kinematic measures related to balance or range of movement. There was evidence that linear displacement of the hip is related to throwing velocity.

Longitudinal Change

Although most participants demonstrated some change in the categorization of the movement patterns used to throw a ball, the amount of change was relatively small and usually confined to a single component. These findings suggest that older adults are relatively stable in their throwing performance across a one-year interval. More careful examination of the movement pattern data, however, suggests that this conclusion should be made tentatively. Individuals categorized at the lowest developmental level in the first year of the study cannot regress further within the classification scheme used here. Individuals placed in level 1 of the forearm action, for example, could not regress further during the second year of the investigation. Further study of individuals who enter an investigation using more advanced movement patterns is necessary.

Subtle pattern changes did appear to take place in some of these older adults. Most changes occurred within the developmental level noted in year one of the study. For example, most participants were classified as taking a contra-lateral, short step over both years of the study (level 3). An informal comparison of performances from one year to the next suggested that many participants shortened their step in year 2, relative to year 1. The categorical descriptions of the
developmental levels of foot action are not sensitive to such small quantitative change. From a biomechanical perspective, however, these changes could be documented and may be indicative of further developmental regression.

While our comparisons between the older adults and the young children and adolescents studied by Halverson et al. [15] do not permit us to determine whether change occurred in the older adults, there were clear differences suggesting decline. The older adults looked more like third graders in the way they threw forcefully and in the velocity of that throw. Of course, the age-related declines suggested by these data must be confirmed longitudinally. It is possible that due to a lack of opportunity or interest these particular adults never demonstrated more advanced movement patterns than those evidenced in this investigation; their present level of skill may be related more to their lack of experience than to regression.

**Gender Differences**

Gender differences found in this investigation were consistent with those reported for younger throwers. In previous studies gender differences in the overarm throw have been identified in children as young as three years of age [13]. The gap in throwing velocities used by male and female participants continues to increase throughout the childhood and adolescent years [15]. Interestingly, the difference in velocity scores of the older adults in this investigation were the same as the difference found for second graders (15 ft/s—4.6 m/s).

The clearest indication of why older men threw at velocities that were faster than those used by older women lies in the movement patterns used by each group. In general, the older men used more advanced movement patterns than did the older women. An investigation by Roberton and Konczak demonstrated that ball velocities could be predicted reliably from the developmental level of movement components in children [19]. Humerus and forearm components were especially strong predictors in their study, accounting for 73 percent or more of the variance. Distinct gender differences were found in humerus and forearm patterns used by our older adults, further corroborating Roberton and Konczak's findings.

It was hypothesized that kinematic measures related to balance and range of motion would distinguish between levels of throwing ability. Initial, gender based analyses resulted in the rejection of this hypothesis. There were no differences among the older throwers in the extent of movement used in their throwing performances, despite large differences in throwing velocities. Although males threw the ball faster, they did not take a longer step into the throw to do it. They did not transfer their weight further back in preparation or bring it further forward at the end of their throw. We did find, however, that the overall, linear displacement was an important predictor of throwing velocity, regardless of gender.

The results of this investigation suggest that older adults are less able, or less willing, to perform some movements as forcefully as their younger counterparts.
Our participants tended to throw using less advanced movement patterns, involving smaller ranges of motion in trunk and arm actions. They took smaller steps, suggesting that either range of motion was limited, or their balance was more tenuous. The result of these limitations in the horizontal displacement of the hip was a throw at a slower velocity. Our conclusions are speculative, because comparisons were made cross-sectionally. A long-term lifespan study is necessary in order to confirm the pattern of differences we found.

In summary, the typical pattern of gender differences documented for younger individuals was found among the older adults tested in this study. Male throwers used more advanced movement patterns to throw faster than female throwers. In addition, some participants demonstrated regression in the movement patterns they used, particularly in humerus and foot actions. A group of kinematic measures failed to uncover clear relationships between throwing velocity and movement pattern used. Movement patterns provided the clearest indications of why some individuals threw faster than others. This suggested that the assessment of qualitative differences in throwing patterns often can be more useful than the measurement of some quantitative values.

ACKNOWLEDGMENTS

The authors would like to thank Mary Ann Roberton for providing the longitudinal data reported in this investigation. Thanks also to Ann Sebren and Michael Bird for their help in data reduction and analysis. Thanks also to two anonymous reviewers for their insightful comments.

REFERENCES

5. A. VanSant, A Life-Span Perspective of Age Differences in Righting Movements, manuscript submitted, 1990.
7. R. Craik, R. Herman, and F. R. Finley, Human Solutions for Locomotion: Intertlimb Coordination, Advances in Behavioral Biology, 18, pp. 51-64, 1976.


Direct reprint requests to:

Kathleen Williams
Department of Exercise and Sport Science
University of North Carolina at Greensboro
Greensboro, NC 27412