Original Article

Distance as a control parameter for place kicking

KRISTI K. MALLY[1] ✉ , REBECCA A. BATTISTA[2], MARY ANN ROBERTON[3]

[1]Department of Exercise and Sport Science, University Wisconsin-La Crosse, USA
[2]Department of Health, Leisure and Exercise Science, Appalachian State University, USA
[3]Professor Emerita, Bowling Green State University, USA

ABSTRACT

Mally KK, Battista RA, Roberton MA. Distance as a control parameter for place kicking. *J. Hum. Sport Exerc.* Vol. 6, No. 1, pp. 122-134, 2011. Using a dynamic systems perspective, this study investigated whether distance functioned as a control parameter that might alter children's place kicking patterns. Nineteen children (mean age = 8.1 years) kicked 3 times at each of 5 randomly ordered distances (1.524, 3.048, 6.096, 9.144, 12.192 meters). All kicks were videotaped. Results indicated that four movement features changed significantly (p<0.01) as a result of the distance kicked. The features were number/type of forward steps in the approach, distance between the feet in the final foot position during approach, position of the shank in the forward leg swing, and leg action in the follow through. These results suggest that distance (or force) may be a control parameter that teachers could manipulate when helping children learn to place kick. **Key words**: DYNAMIC SYSTEMS, CONTROL PARAMETERS, PLACE KICKING.

INTRODUCTION

Distance as a control parameter for place kicking
Fundamental movement skills comprise much of the movement curriculum for early childhood and elementary physical education programs. The purpose behind most movement experiences during these early years is to provide students with opportunities to practice and refine these basic skills so they are equipped with the pre-requisites for more complex, specialized movements as they progress through school. Traditionally, physical educators and coaches use adult or advanced movement forms as their templates to design learning tasks and to assess movement outcomes when teaching these foundational skills. Physical educators often model the preferred form visually, pointing out the critical elements of the movement. They then provide multiple repetitions for the learner to experiment and refine the movement, and offer instructional cues based on the desired form. Little attention is given to other factors within the task and environment that may also potentially evoke movement change. The dynamic systems approach focuses on the causes for shifts in movement behavior from one pattern to another (Ulrich, 1997). It, therefore, may provide a basis for physical educators and coaches to make decisions about task design and manipulation that would serve as an alternative or supplement to traditional teaching methodology.

A dynamic system is any system that self-organizes as characteristics internal and external to the system interact and change. The human body is an example of a dynamic system whereby movement behavior arises from the interaction of multiple sub-systems. Newell (1986) suggested three subsystems that can change movement patterns: the characteristics of the specific task, the physical and socio-cultural environment, and the unique characteristics that the individual brings to the task. The dynamic interaction of these factors determines what the movements will look like when they are performed. Thelen (1995) suggested that when one aspect of the person-task-environment system, such as muscle strength, confidence, or terrain, is changed, the other aspects are initially disrupted; after a period of instability, these parts self-organize to accommodate for the original disruption, resulting in a new, preferred way of performing the skill. Those adhering to the dynamic system approach strive to understand the overall behavior of the entire system, not by breaking it into separate parts, but by inquiring how and under what situations the various parts cooperate to produce movement behavior change (Ulrich, 1997). Variables within a dynamic system that evoke change in movement patterns when scaled to a critical value are referred to as control parameters (Southard, 2007). Control parameters set up the conditions for change to occur, not by dictating that change, but by creating an interaction of variables that supports the change. In theory, any characteristics within the individual, the environment, or the task could serve as a control parameter. One of the goals of research is to detect the control parameters for various motor skills.

Task characteristics as control parameters
The impact that task characteristics have on movement behaviors has intrigued motor behavior scholars for years (Gentile, 1972; Gentile, 1987; Herkowitz, 1978; Langendorfer, 1987; Langendorfer, 1990; Roberton, 1987; Thelen and Ulrich, 1991). For instance, Halverson (1966) noted the effect that the task goal or purpose had on subsequent movement patterns used to perform a skill. She suggested that what a teacher observes a child do at any one time does not answer the question of what that child could do if the teacher knew enough to set the conditions of the task to stimulate the emergence of the desired movement. The demands of the task, which include equipment, organization, rules, requirements and goals, act as one sub-system in a dynamic interaction that has potential to initiate change in the way a skill is performed.

For instance, Newell, Scully, McDonald, and Baillargeon (1989) demonstrated how the grip pattern produced when reaching for an object is an emergent property of the relationship between the person and the task characteristics. Task relevant information caused even young infants to shift their grasping patterns. The size of the object to be grasped relative to the child's hand size engendered changes in the pattern of the grip, thus acting as the control parameter.

Liu and Burton (1999) studied the relationship between the distance to the hoop and the form used to shoot a basketball. As distance from the hoop was increased, the shooting form most commonly used at shorter distances was no longer adequate. Participants shifted from using an ipsilateral to a contralateral forward foot position, a high to low hand position, no trunk rotation to trunk rotation, and a low jump to a high jump when distance was increased.

Task characteristics also seem to affect throwing. Hamilton and Tate (2002) found that altering target size did not significantly affect throwing pattern, but increasing distance from the target significantly altered the movement patterns used in the trunk, foot, and arm. After examining all throws made during seven collegiate baseball games, Barrett and Burton (2002) reported that task purpose and situation significantly impacted the movements used to complete a throw. Throws requiring more force or distance, often used by pitchers and outfielders, resembled developmentally advanced throwing patterns, while throws requiring quickness or short distances used developmental alternatives to the typical adult pattern. Although all study participants were presumably capable of throwing using the most advanced form, many did not due to the task characteristics.

Task variables and kicking
The few findings related to kicking support much of what has already been discussed. Chow, Davids, Button, and Koh (2007) recently studied the effect that task goal, specifically height and accuracy, had on kicking coordination as a function of skill level. They found that these task constraints had a more profound effect on the kicking form used by skilled and intermediate players. Novice players tended to drive the ball regardless of task goal, whereas more skilled players were more likely to freeze proximal joints while utilizing the more distal joints in an attempt to control the ball for accuracy. Button, Smith, and Pepping (2005) also analyzed the effects of different task goals on soccer kicking. They indicated that tasks emphasizing maximum ball velocity resulted in greater range of motion in the lower body joints, whereas range of motion decreased during accuracy tasks. Teixeira (1999) examined how speed and accuracy interplay to generate precise yet powerful kicking movements. He manipulated ball size and target specifications and found that as target area was restricted, movement speed was reduced.

Because task characteristics are controllable by the teacher, they should be of interest to scholars studying how teaching causes change in movement behaviors. Using the idea of a control parameter, researchers can identify the impact that a task characteristic has on the way a mover performs a skill by scaling specific task characteristics to particular values and then observing the resultant movement patterns. The current study builds particularly on the findings of Hamilton and Tate (2002) and Liu and Burton (1999) by investigating the impact that the distance to be kicked has on the movement displayed by children place kicking a stationary ball. The results of this study are aimed at informing physical educators, coaches, and others striving to improve the movement skills of children.

MATERIAL AND METHODS

Participants
Nineteen children (12 boys and 7 girls) (mean age = 8.1 years; standard deviation = 1.8 years), enrolled in an after school day care program, volunteered to participate in the study. All procedures were approved by the university's Institutional Review Board for the Protection of Human Subjects. Parents provided informed consent prior to allowing their children to participate in the study and children provided verbal assent prior to participating in any testing procedures. Data were collected in the gymnasium located at the school.

Data collection
The kicking space was set up according to the following design: an 8 ½" gator skin ball was placed on a rubber deck tennis ring 4.572 m from one end of the gym; brightly colored cones were placed at 1.524, 3.048, 6.096, 9.144 and 12.192 meters distances from the ball; participants were allowed to use the 4.572 meter of space between the gym wall and the ball in any way they needed to execute the kick.

One researcher stood at a designated cone. Participants were asked to try to kick the ball so the researcher could catch it without having to move from the area around the cone. We recognize that using an investigator to help the children see the distance to be kicked introduced an element of accuracy in the task. Participants kicked three times at each distance, totaling 15 kicks. The order in which the distances were kicked was randomized for each participant, but all three kicks at one distance were completed before moving on to the next distance. After each kick participants were given motivating and/or reinforcing general feedback. After completion of the three kicks at each distance they were reminded of the task goal: to kick the ball so it would reach the investigator. Participants were not allowed to view each other during the kicking process. The only individuals in the gym during each round of kicking were two researchers, an assistant, and the child who was kicking.

All kicks were recorded using a JVC hard drive camcorder. The camcorder was secured to a tripod which was positioned to the side at a 30 degree angle to the child's approach. The camera was approximately 9.144 m away from the kicking spot in order to capture each participant's entire kicking action including approach and follow through.

Data reduction
To reduce the data from the videotapes, we separated each kick into 12 specific movement features determined from the developmental (Bloomfield et al., 1979; Lisy, 2002; Wickstrom, 1983), and biomechanical literature (Lees and Nolan, 1998; Roberts and Metcalfe, 1968). We hypothesized that these movement features might be sensitive to distance kicked. From pilot data we then developed an observational checklist of the possible movements that could occur within each feature (see Tables 1-3).

Using this checklist, one of the investigators categorized each child's kick from the videotapes. This investigator was blind to the distance condition under which each kick was performed. Following reduction from the videotapes, each child's data were organized according to the actual distance condition. The modal category displayed at each distance became the child's descriptive category for that specific movement feature.

Data analysis

Independent samples t-tests were performed on the children's age, height, weight, and sitting height to height ratio (Table 4) to determine any significant differences between boys and girls. Since there were none (p>0.05), we grouped the children for the remaining analyses. Since the movement data were nominal and repeated measures, the investigators used the Cochran-Mantel-Haenszel (C-M-H) Statistic (Hall et al., 2000; Kuritz et al., 1988) to determine if different movement categories were displayed by the children when they were asked to kick different distances. Alpha was set at 0.01/analysis to control experiment-wise error. Significant C-M-H statistics were followed by graphical analyses to determine the changes accounting for the significance.

Table 1. *Kicking for force: Approach categories.*

Movement Feature	Category Description
Approach: Number and type of forward steps	A None B Weight shift in place C One (1 ft length) D Several – last is a step E Several – last is a leap (flight = 1 frame) F Several – last is a leap (flight = 2+ frames)
Final foot position: Length between feet (in foot lengths)	A 1 or less B 1 to 2 C Greater than 2
Final foot position: Support leg position in relation to ball	A Behind (more than 1 foot length) B Behind (less than 1 foot length) C Alongside (ball blocks foot view) D Diagonally behind more than a foot E Diagonally behind less than a foot
Final approach step: Opposite arm position	A Bilateral above waist B Bilateral at or below waist C Adducted D Abducted E Opposition
Final approach step: Homolateral arm position	A Bilateral above waist B Bilateral at or below waist C High guard position D Adducted E Abducted F Opposition

***Table 2.** Kicking for force: Forward leg swing.*

Movement Feature	Category Description
Forward leg swing: Initial thigh position	A In line with trunk B Hyperextended due to backswing C Hyperextended due to approach D Ahead of body
Forward leg swing: Position of the shank	A Foot below horizontal B Parallel to floor C Foot above horizontal
Forward leg swing: Opposite arm action	A Bilateral above waist B Forward bilaterally – below waist to above C Bilateral to opposition D Opposition to bilateral E Adducted F Abducted G Opposition
Forward leg swing: Homolateral arm action	A Bilateral above waist B Forward bilaterally – below waist to above C Bilateral to opposition D Opposition to bilateral E Primarily adducted above waist F Primarily abducted below waist G Abducted H Opposition

***Table 3.** Kicking for force: Forward leg swing contact and follow through.*

Movement Feature	Category Description
Contact: Angle of knee (estimated in back of leg)	A < 90 degrees B Equal or > 90 degrees
Contact: Upper trunk position	A Upright B Flexed forward C Extended backward
Follow through: Leg action	A In place/ahead of other leg B Fall/step backward C Step forward past ball tee D Flight – hop E Flight – leap F Flight - jump

RESULTS

*Reliability and validity of the observation checklist*
Before analyzing the data, we examined the inter-observer objectivity between the first investigator who categorized all trials, and a second investigator who categorized 25 random trials. Exact agreement ranged from 79.2-100% across the individual kicking features and was 92.5% exact agreement for all trials combined. We also checked the validity of the observation tool by asking whether each possible category within the 12 movement features (see Tables 1-3) had appeared at some time in at least one child. Indeed, all the categories were observed with the exception of 1) category A in *Contact: Angle of knee* and 2) category C in *Final approach step: Homolateral arm position.* Thus, we concluded the observation tool had been a useful descriptor of the children's movement.

***Table 4.*** *Physical characteristics of participants.*

Characteristic	Boys (n=12)		Girls (n=7)	
	M	*SD*	*M*	*SD*
Age (years)	7.8	1.8	8.4	2.0
Height (cm)	126.9	9.9	127.6	11.3
Weight (kg)	29.4	8.1	35.9	15.1
Sitting height to height ratio (%)	52.6	1.9	52.4	2.6

Our primary question was whether distance functioned as a control parameter that might alter the kicking pattern. Four of the movement features examined changed significantly across the different distances:

1. Approach: Number and type of forward steps (p=0.006). Post-hoc analysis (Figure $1_{a\text{-}b}$) indicated the children showed fewer instances of category C (taking only 1 step) as distance increased until no child displayed this behavior when asked to kick the ball 12.192 m (Figure 1_a). Meanwhile, instances of categories E and F (taking several steps ending in a short or long leap) increased over the distances from approximately 0% and 6% to 21% and 26% respectively (Figure 1_b). No step at all (category A) was displayed by 11% of the children when asked to kick 1.524 m but never displayed thereafter except at 9.144 m. In contrast, categories B (weight shift in place) and D (several steps) were used by a number of children at each of the distances kicked.
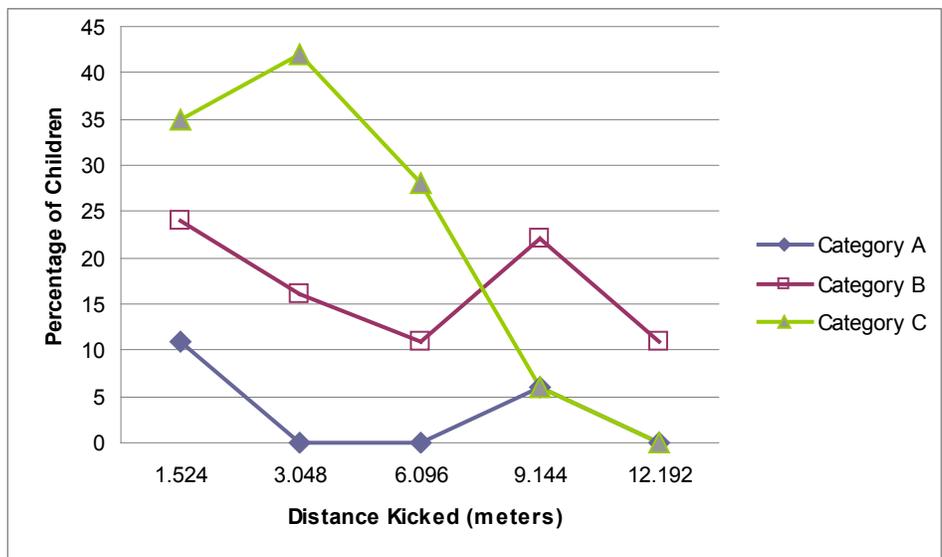
(a)
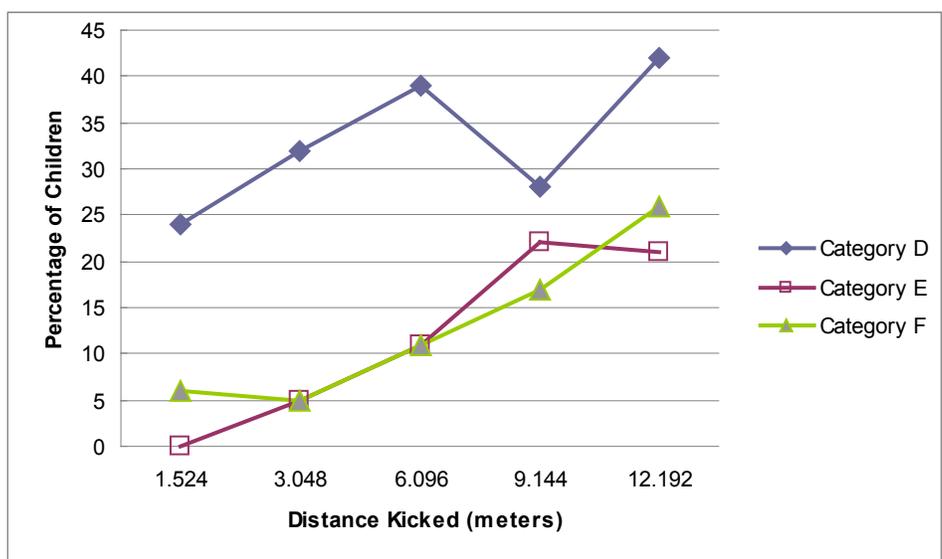
(b)

Figure 1. *Percentage of children at each distance who displayed a category within Approach: Number and type of forward steps. Categories descriptors have been placed into two graphs (a and b) for clarity.*

2. *Approach: Final foot position – Length between feet* (*p*=0.0001). As the distance to be kicked increased, the distance between the feet in the final foot position also tended to increase (see Figure 2). Sixty-three percent of the children had their feet less than their own foot length apart when kicking for 1.524 m (category A) while only 17% of the children had their feet this close together at 12.192 m. Conversely, 36% of the children had their feet more than 2 foot-lengths apart at 1.524 m (category C) while over twice that many (72%) showed this behavior when kicking 12.192 m.
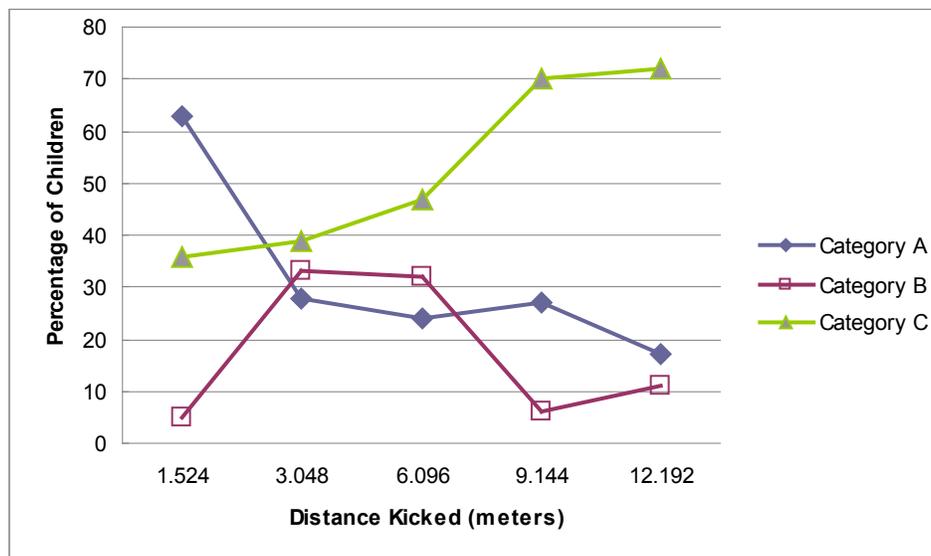
Figure 2. *Percentage of children at each distance who displayed a category within Final foot position: Length between feet.*

3. *Forward leg swing: Position of the shank* (*p*=.003). As Figure 3 shows, category A (foot below the horizontal) decreased strongly in frequency over distance while shank parallel to the floor (category B) increased. Foot above the horizontal (category C) was displayed relatively frequently at all distances and seemed to be increasing slightly as distance increased.
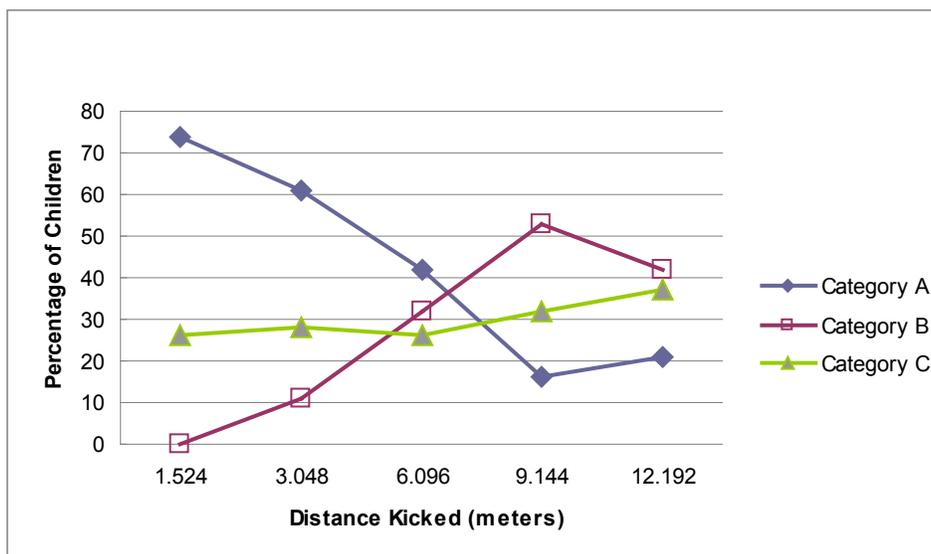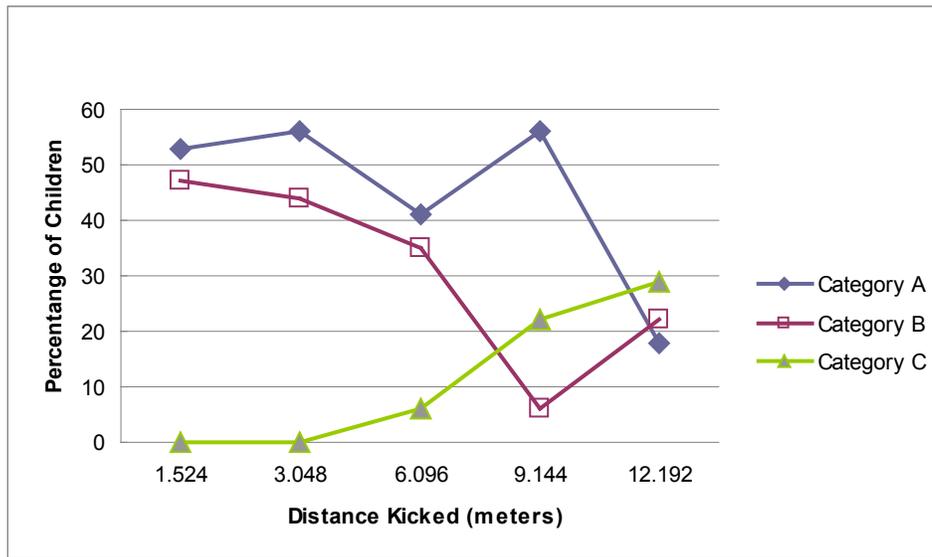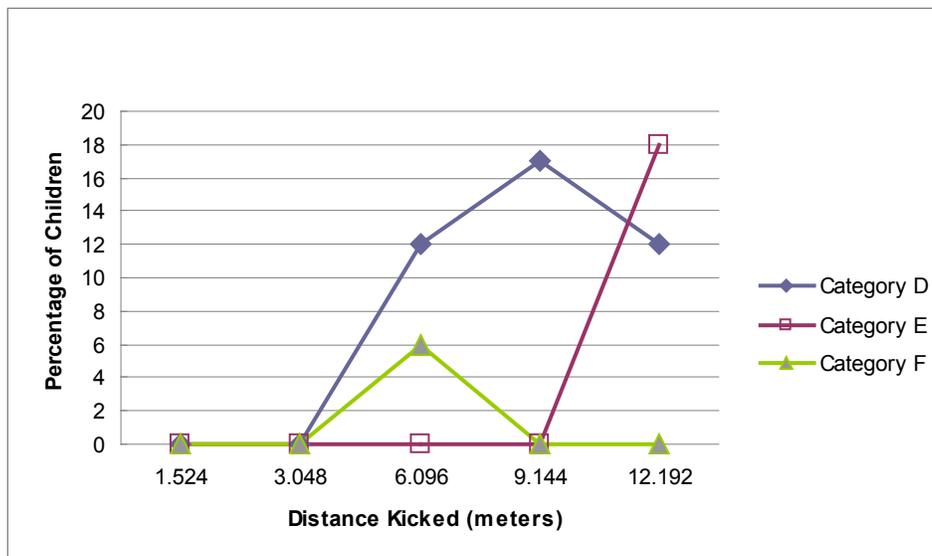

Figure 3. *Percentage of children at each distance who displayed a category within Forward leg swing: position of shank during.*

4. *Follow-through: Leg action* (*p*=0.0006). The frequency with which the children placed their kicking foot back where it began its forward swing or with which they fell backward after the kick (categories A and B) decreased strongly as the distance to be kicked increased (Figure 4a). Instances of stepping forward or hopping after the kick (categories C and D) increased over distance although the hop frequencies began to decline while the leap (E) increased at the farthest distance. Jumping (F) was only seen modally in 6% of the children at 6.096 m.

(a)

(b)

Figure 4. *Percentage of children at each distance who displayed a category within Follow through: leg action. Categories have been placed into two graphs (a and b) for clarity.*

DISCUSSION AND CONCLUSION

The primary purpose of the present study was to determine if the distance to be kicked impacted children's kicking patterns. The results indicated that distance did act as a control parameter for four features of the kicking motion. With no instruction or demonstration, the children spontaneously changed their movement relative to the distance they were asked to kick.

We recognize that as kicking distance increases, the need to generate more force also increases, indicating that force rather than distance may be the controlling factor. More force requires greater range of movement and acceleration of body parts, and greater linear velocity from an approach. Our data indicated that as the children were asked to kick farther, they tended to change their approach to the ball by adding steps and, in some cases, leaps before striking the ball. They also increased the length of their final step/leap. These changes served to increase the linear velocity of their body. During the forward swing of the kicking leg, the shank tended to incline more obliquely upward and back so that the children's foot was parallel with or even above the horizontal as it moved forward. This behavior most likely reflected greater acceleration of the thigh in the kick, which causes greater flexion at the knee. A slowly-moving thigh tends to be accompanied by an obliquely downward shank while a rapidly accelerating thigh will raise the shank obliquely upward. Finally, with the demand for greater distance, there was an increasing tendency after ball contact for the children to dissipate their momentum forward beyond the kicking tee rather than backward.

Manipulating control parameters to elicit change in movement pattern
Our results resemble those reported by Liu and Burton (1999), Hamilton and Tate (2002), and Barrett and Burton (2002). Liu and Burton (1999) reported that the form used to shoot a basketball shifted when the distance was increased. Their findings supported the idea that as force requirements increased with the greater distance to the basket, the shooting form used at shorter distances was no longer sufficient, and therefore had to change. Hamilton and Tate (2002) reported that children self-organized their throwing to more advanced patterns, to accommodate for increasing distance, while Barrett and Burton (2002) noted that when the goal of the task was to throw for force and distance, baseball players used more advanced forms of the overhand throw. Our findings suggest that increasing the distance to be kicked induces movement changes within aspects of the approach, forward leg swing, and follow through.

Applications to teaching
Although more research is needed on larger, more diverse groups of children, we see some practical implications from this study. When designing practice sessions, practitioners should consider the potential effect of the task in relationship to their teaching purpose. If they hope to elicit or refine more advanced form, then it may prove beneficial to increase the distance between the kicker and the target. Another option is to design goals and feedback that will encourage children to generate more force: for instance, using targets that make noise when hit hard (see Herkowitz (1978) for other examples).

In their physical education textbook, Gallahue and Donnelly (2003) listed a set of common, developmental difficulties for physical educators to consider when observing students performing the kicking motion. The list included: restricted backswing, failure to step forward with non-kicking leg, poor opposition of arms and legs, jabbing at ball without follow-through, and failure to use summation of forces. The findings from the present study suggest that if students are moved farther from the target they may spontaneously alter the way they approach the ball, the length of their final step, the forcefulness of their leg swing, and their follow through leg action, the very difficulties Gallahue and Donnelly listed.

ACKNOWLEDGEMENTS

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