

Research Article

Factors Influencing Self-selected Throwing Styles of Young Children under the Maximum Distance Thrown Effort

Ratanapinuchai, J.*, Silsupadol, P.**

Abstract

Objective: Factors affecting self-selected throwing styles of young children as they threw a ball as far as possible was the focus of this study.

Materials and methods: Thirty-two healthy boys (2-7 years old) participated. Subjects were asked to throw a light plastic ball from the standing position with no demonstration of the throwing pattern for five trials. A video camera was used to record the performance of children. The researcher then demonstrated a mature overarm pattern of throwing which included verbal explanation. Another three trials of the child's throwing motion were then recorded. The isometric strength of the external rotators, internal rotators and horizontal abductor of the shoulder were measured using a handheld dynamometer.

Results: Five throwing patterns could be classified from 160 trials, that is, the underarm (UA), the immature overarm pattern 1 (IM1) and 2 (IM2) and the mature overarm pattern 1 (MP1) and 2 (MP2). The youngest boys (2-3 years old) chose only the UA, IM1 and IM2 whereas most of the oldest boys (6-7 years old) selected MP1 and MP2 except only one subject who threw in the UA pattern. Subjects at the age of 4-5 years demonstrated the high variability of the self-selected throwing patterns. This group of boys used all 5 classified throwing patterns. Some subjects demonstrated intra-variability of throwing styles. This intra-variability occurred only from the UA to the IM1 or the IM2. The isometric strength of the shoulder muscles showed a non-significant correlation with the selected patterns when the effect of age was partialled out. Following a demonstration of the mature overarm pattern, some subjects continued to use an UA or an IM style.

Conclusion: The results suggest that under the maximum distance thrown condition, selection of throwing patterns depend on the age and the knowledge of the mature pattern. The MP tends to develop at the age of 4–5 years and the UA seems to be the simplest pattern when compare to the overarm style. Bull Chiang Mai Assoc Med Sci 2001; 34: 190–201.

Keywords: Development, throwing

* Department of Physical Therapy, Faculty of Associated Medical Sciences;

** Department of Orthopedics, Faculty of Medicine, Chiang Mai University.

บทคัดย่อ: ปัจจัยที่มีผลต่อการเลือกรูปแบบการขว้างบอลให้ไกลที่สุดในเด็กเล็ก

จงจินตน์ รัตนานันทชัย*, ปฎิมา ศิลสุภคด**

วัตถุประสงค์: เพื่อศึกษาปัจจัยที่มีผลต่อการเลือกรูปแบบการขว้างบอลให้ไกลที่สุดในเด็กเล็ก

วัสดุและวิธีการ: ศึกษาในเด็กชายปกติจำนวน 32 คน อายุระหว่าง 2–7 ปี โดยให้ผู้ถูกทดลองขว้างบอลพลาสติกที่มีน้ำหนักเบาในท่ายืนให้ไกลที่สุดเท่าที่จะทำได้จำนวน 5 ครั้ง โดยผู้วิจัยไม่แสดงท่าการขว้างบอลให้เด็กดู จากนั้นผู้วิจัยสาธิตแสดงท่าขว้างบอลรูปแบบ overarm ให้เด็กดูและให้เด็กขว้างบอลอีก 3 ครั้ง ทำการบันทึกภาพวิดีโอการขว้างบอลของเด็กเพื่อนำมาวิเคราะห์รูปแบบ และวัดความแข็งแรงของกล้ามเนื้อข้อไหล่ ได้แก่ external rotators, internal rotators และ horizontal abductor โดยใช้ handheld dynamometer

ผลการศึกษา: จากการขว้างบอลจำนวน 160 ครั้ง สามารถจัดกลุ่มได้ 5 รูปแบบ คือ Underarm (UA), Immature overarm pattern 1 (IM1) และ 2 (IM2), Mature overarm pattern 1 (MP1) และ 2 (MP2) เด็กที่มีอายุน้อยที่สุด (อายุ 2–3 ปี) เลือกการขว้างบอลแบบ UA, IM1 และ IM2 เท่านั้น ขณะที่เด็กที่มีอายุ 6–7 ปี เลือกรูปแบบ MP1 และ MP2 เป็นส่วนมาก มีเด็กเพียง 1 รายในกลุ่มอายุ 6–7 ปีที่เลือกการขว้างแบบ UA เด็กที่มีอายุ 4–5 ปี มีรูปแบบการขว้างบอลหลากหลายมากกว่าเด็กในช่วงอายุอื่น โดยมีผู้เลือกรูปแบบต่างๆ ทั้ง 5 ลักษณะ นอกจากนี้ยังพบว่าเด็กบางคนยังเลือกการขว้างบอลหลายลักษณะ โดยการเปลี่ยนรูปแบบการขว้างจากรูปแบบ UA ไปเป็นรูปแบบ IM1 หรือ IM2 เท่านั้น ไม่พบความสัมพันธ์ระหว่างความแข็งแรงของกล้ามเนื้อข้อไหล่กับรูปแบบการขว้างบอลที่เด็กเลือกใช้เมื่อตัดปัจจัยร่วมที่มีผล ได้แก่ อายุของเด็กออก ภายหลังจากผู้วิจัยแสดงท่าการขว้างบอลแบบ overarm ให้เด็กดู พบว่าเด็กบางคนยังคงเลือกใช้รูปแบบ UA หรือ IM อยู่

สรุป: ผลการศึกษานี้แสดงให้เห็นว่าในเงื่อนไขของการขว้างบอลให้ไกลที่สุด รูปแบบการขว้างบอลที่เด็กเล็กเลือกใช้ขึ้นกับอายุ ความรู้เกี่ยวกับลักษณะการขว้างบอล การขว้างแบบ MP เริ่มพัฒนาในเด็กอายุ 4–5 ปี

และการขว้างบอลแบบ UA เป็นท่าที่ง่ายเมื่อเทียบกับรูปแบบ MP วารสารเทคนิคการแพทย์เชียงใหม่
2544; 34: 190-201.

คำรหัส: พัฒนาการ, การขว้าง

* ภาควิชากายภาพบำบัด คณะเทคนิคการแพทย์;

** ภาควิชาศัลยศาสตร์ออร์โธปิดิกส์ คณะแพทยศาสตร์ มหาวิทยาลัยเชียงใหม่

Introduction

Throwing is a skilled multijoint movement which developed after children are capable of ambulating without assistance and it is one of a movement in a category of object-control skills¹. Different throwing patterns can be classified such as underarm, sidearm and overarm throw. However, most research described is related to an overhand throw with only a few studies presenting information associated with an underarm pattern. Thus, the role of the underhand pattern in the development of throwing remains unclear.

Development of the overarm throwing develops through several stages from throwing using the elbow to the incorporation of shoulder and elbow movements. A young child normally throws using extension of the elbow joint. Maturation of the motion causes a change from flexion and extension of the elbow and the shoulder joint to rotation and horizontal adduction of the shoulder joint¹. Throwing movement tends to progress from an anterior-posterior plane to a horizontal plane. In addition, the base of support changes from

a stationary to a shifting position².

A number of factors have been identified as influencing the overarm throwing. These factors included age^{1, 3} and gender³. Males tend to show a more mature throwing pattern than females⁴. Five-year-old children demonstrate some components of an overarm throw incorporating shoulder rotation and forward shifting of the body⁵. Other factors involved balance³, sociocultural factors such as sport participation³, training⁶, verbal cues⁷, ball size⁸, mass and velocity of upper limb segment⁹.

Instruction also influenced the overarm throwing pattern or technique¹⁰. However, Halverson and coworkers¹¹ stated that instruction showed no significant changes to the children's ball-throwing velocities. Payne and Isaacs¹ concluded that throwing pattern development may develop before the elements of the pattern can be appropriately and sequentially timed. Major component of the mature throwing pattern is timing of segmental rotation. If coordination of body segment rotation is not appropriately linked with arm

action the pattern might look appropriate but no gain in ball velocity will be achieved.

Muscle strength is another factor likely to effect the development of this motor activity. For example, it has been found that the size of the arm muscles is related to the distance that can be thrown, that is the greater the muscle bulk, the greater the distance which can be thrown⁴. This research demonstrated that muscle strength is related to the overarm throwing distance, however, no evidence has been reported which supports a relationship between the strength of the relevant shoulder muscles and the self-selected throwing pattern in young children.

According to the dynamic systems theory, patterns of movement can emerge from the interaction of system components within the context of a given task¹². This interaction is called as self-organizing of the system. The system may involve neurophysiological, biomechanical, social, and other contextual factors. Under the controlled gender and conditions of throwing, that is without verbal cues and using a proper ball size and weight which can use for one hand throwing, we aimed to explore self-selected pattern of throwing in 2-7 years old boys. The hypotheses are that the self-selected throwing patterns, based on dynamic systems concept, may depend not only on age but also on the other factors. Maximum throwing distance was set as a goal of movement in the study. The shoulder muscles strength and the knowledge of the mature

overarm patterns were testified the contribution on the self-selected throwing patterns.

Materials and Methods

Subjects

Thirty-two healthy boys with typical development aged between 2-7 years participated in the study. The boys were studying at primary schools in the Chiang Mai Province of Northern Thailand. All subjects were right handed. Teachers at the schools who reported the dominant hand of each subject from observations of eating and writing activities established handedness.

Protocols

The demographic data recorded and the dates of birth of all subjects were collected from their school records. After an explanation and a short period of instruction, the isometric strength of the external rotators, the internal rotators and the horizontal adductor of the right shoulder joint were measured using a hand-held dynamometer in a seated position. Isometric muscle strength of these three muscles was chosen for examination in the study, because they are considered to be essential for an overarm throw. Subjects were asked to abduct the shoulder joint at 90 degrees and flex the elbow joint at about 90 degrees, while the arm segment was rested on a table. A push pull dynamometer was placed at the distal end of the forearm to measure the strength of the external and internal rotators. For horizontal adduction, a push pull

dynamometer was positioned at the medial side of the distal end of the humerus. Subjects were informed of the procedure and were allowed to practice a few times before the assessment was performed. The average of three measurements was used for analysis.

One video camera was set on the right side of subjects at about 4.6 meters. Subjects were asked to throw a light plastic ball (diameter 7 cms) as far as they could using their own style of throwing. Five repetitions were permitted. The researcher then demonstrated a mature overarm pattern of throwing which included verbal explanation. Another three trials of the child's throwing motion were then recorded to determine the effect of the knowledge of the mature overarm pattern on the child's performance. No practice was allowed prior to the last three trials being recorded.

Data analysis

Subjects were classified into different groups according to their self-selected throwing patterns. The strength of each muscle in each throwing pattern was compared using Kruskal-Wallis Test with a level of significance of 0.05. The Mann-Whitney Test

was used as a post-hoc test with $p = 0.005$. Relationships between the pattern of throwing: pre- and post-demonstration and the strength of the shoulder muscles were tested using the partial correlation with age as a controlled factor. Intravariability of self-selected throwing styles in each subject was also determined from two plots of throwing patterns for the initial five trials according to the self-selected patterns and to the age (Fig 1 and 2).

Results

Reliability of the isometric strength measurement

The intratester reliability of the isometric muscle strength measurement of the shoulder joint established by repeated measurements in a pilot group of eight children, was not included in the study. The intraclass correlation coefficient (ICC) for the measure of isometric muscle strength of each muscle group were 0.98, 0.97 and 0.95 for the shoulder external rotators, the internal rotators and the horizontal adductor, respectively. The demographic data for the subjects is presented in Table 1.

Table 1 Demographic data for subjects according to age.

Subject	n	Age (year)	Weight (kg)	Height (cm)
2-3 years	9	2.60 (0.49)	13.83 (2.35)	93.78 (5.26)
4-5 years	11	4.13 (0.53)	17.41 (2.98)	104.32 (5.29)
6-7 years	12	5.64 (0.49)	20.88 (2.80)	114.75 (3.47)

Standard deviations are presented in parenthesis

Self-selected pattern of throwing

Thirty-two boys performed different patterns of throwing, which could be classified into 5 styles;

a) the underarm throw (UA) in which a ball was thrown using mainly a movement of the shoulder joint with the hand positioned below the shoulder joint,

b) the immature overarm pattern 1 (IM1) in which subjects threw a ball using flexion and then extension of the elbow joint with no rotation of the shoulder joint and the position of the hand always being higher than the level of the shoulder joint at the commencement of the throw,

c) the immature overarm pattern 2 (IM2) in which subjects demonstrated external rotation of the shoulder joint at the starting position but used horizontal adduction to throw the ball forward rather than internal rotation of the shoulder joint,

d) the mature overarm pattern (MP1) in which subjects utilized shoulder rotation to throw a ball but did not show any forward weight shifting,

e) the mature overarm pattern (MP2) in which subjects performed the same movement as in MP1 with forward weight shifting of the body.

Intravariability of throwing patterns

Intravariability of throwing patterns of individual subject in each group according to

the self-selected patterns is presented in Fig. 1. Most subjects used a consistent style of throwing. Subjects who selected a mature overarm pattern were consistent with the mature style for five trials. Four subjects changed their patterns from an underarm to an immature overarm throw after a few trials (Fig. 1). The plot of intravariability of throwing pattern of individual subject according to the age is presented in Fig 2. Two to three years old boys selected the UA or the IM1 or the IM2 whereas most of the oldest boys (6-7 years old) used the MP1 or MP2 with the exception of only one subject. Inter-subject variability of the selected pattern was pronounced in the 4-5 years old group. These results demonstrated the effect of age on the self-selected throwing style and intra-variability of pattern occurred mainly when an underarm pattern was initially selected.

Thus for the initial trial we found the ratio of underarm to overarm pattern equal to 5:13 and after the few trials, the ratio of the underarm to overarm was changed to 5:27.

Knowledge of the mature overarm patterns

After the demonstration, more subjects could throw in the mature style (Table 2). Surprisingly, some boys had some difficulties and could not imitate the mature pattern being presented and an UA style was still chosen. These boys were 2-3 years old. Older boys were selected only the overarm pattern.

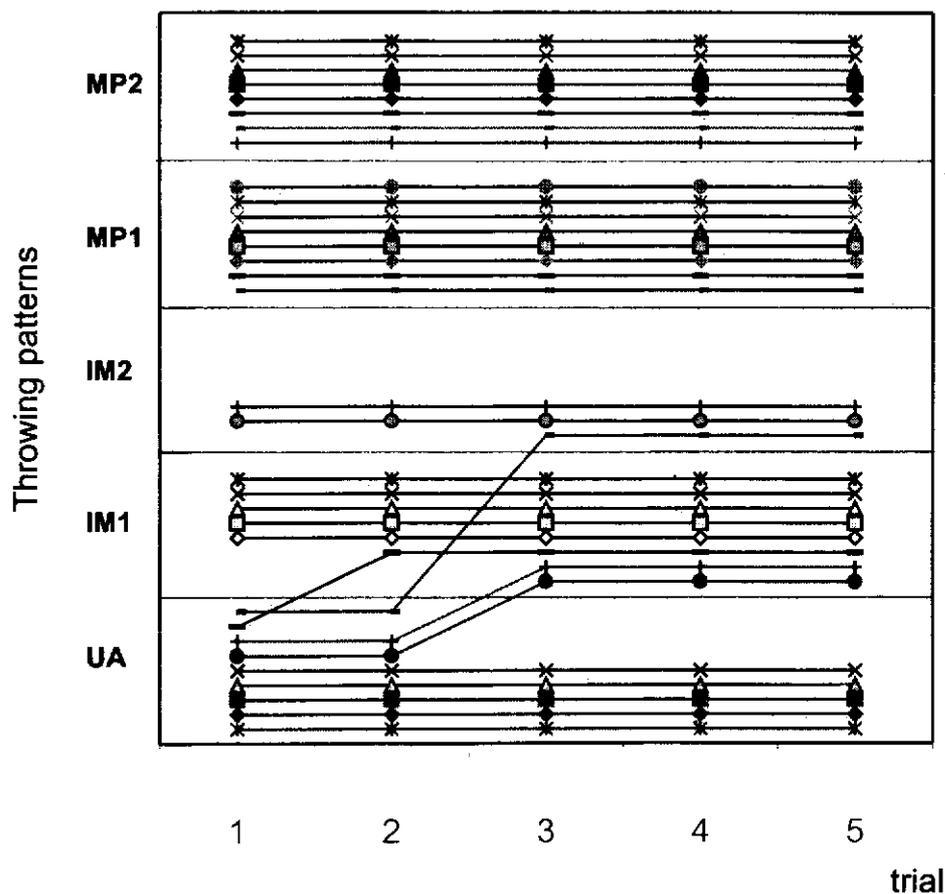


Figure 1 Intravariability of throwing pattern for each subject: pre-demonstration. Each line represents each subject. (MP2 = mature overarm pattern 2, MP1 = mature overarm pattern 1, IM 2 = immature overarm pattern 2, IM 1 = immature overarm pattern 1, UA = underarm throw)

Table 2 Number of subjects in each throwing pattern pre and post demonstration

Throwing pattern	Pre-demonstration	Post-demonstration
UA	5	3
IM1	8	4
IM2	3	5
MP1	8	9
MP2	8	11

UA = underarm throw, IM1 = Immature overarm pattern 1, IM2 = Immature overarm pattern 2, MP1 = Mature overarm pattern 1, MP2 = Mature overarm pattern 2

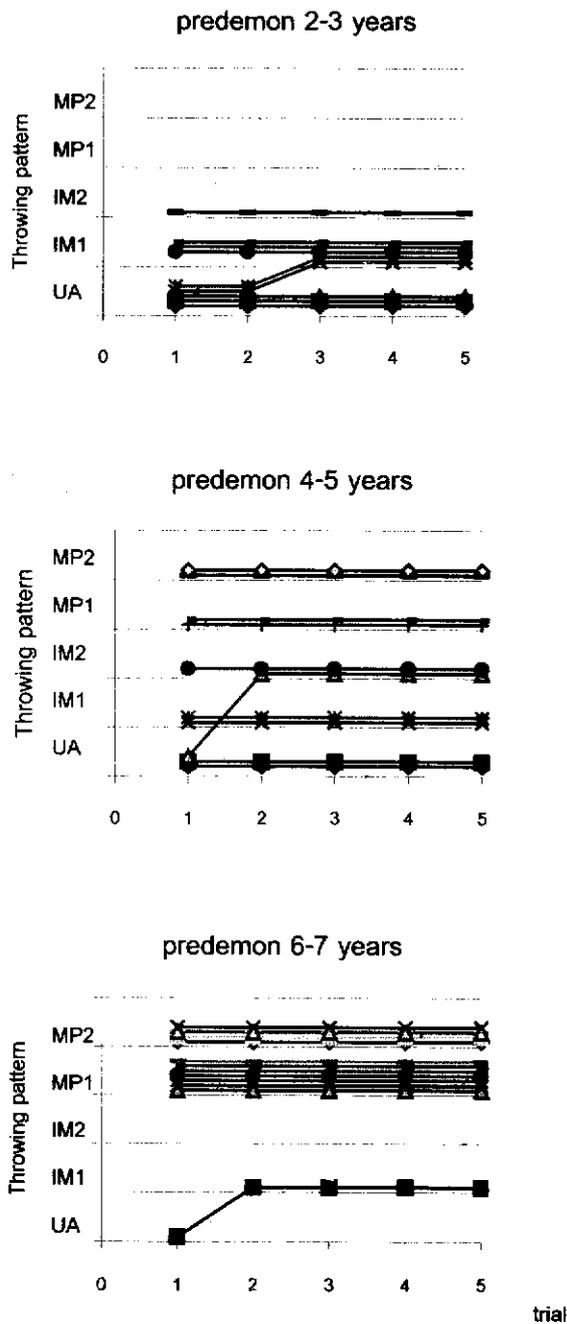


Figure 2 Intravariability of throwing pattern for each subject: pre-demonstration according to the age of subjects. Each line represents each subject. (MP2 = mature overarm pattern 2, MP1 = mature overarm pattern 1, IM 2 = immature overarm pattern 2, IM 1 = immature overarm pattern 1, UA = underarm throw)

Muscle strength

The unequal sample size in each throwing pattern is presented (Table 2), therefore, the nonparametric Kruskal-Wallis test was selected as a statistical test (Table 3). The external rotators and the internal rotators pre-demonstration (Table 3) showed a statistical difference among patterns of throwing ($p = 0.027$ and 0.025 , respectively). For post-demonstration, only the internal rotators (Table 3) showed a statistically significant result among the five defined patterns ($p = 0.038$). The isometric strength of the horizontal adductor of the shoulder joint was not significantly different for each pattern of throwing either pre- or post-demonstration.

Ten comparisons between five throwing patterns were determined using the Mann-Whitney Test with the level of significance 0.005 ($0.05 / \text{number of comparisons}$). For the pre-demonstration (Fig 3a and 3c), only the strength of external and internal rotators between the IM1 and MP2 were significantly different ($p = 0.005$ and 0.002 , respectively). For the post-demonstration (Fig 3e and 3f), the strength of external and internal rotators between the UA and MP2 showed a significant difference ($p = 0.005$ and 0.005 , respectively). The significant result for the external rotators identified when using the Mann-Whitney Test but not the Kruskal-Wallis Test might be due to the small sample size in the underarm group after the demonstration ($n = 3$).

These results suggest that subjects who

Table 3 Kruskal-Wallis Test of each muscle group in different throwing patterns : pre- and post-demonstration (* p < 0.05)

Conditions		External rotators	Internal rotators	Horizontal adductors
Pre-demonstration	Chi-square	10.933	11.135	9.404
	df	4	4	4
	p	0.027*	0.025*	0.052
Post-demonstration	Chi-square	8.967	10.134	9.253
	df	4	4	4
	p	0.062	0.038*	0.055

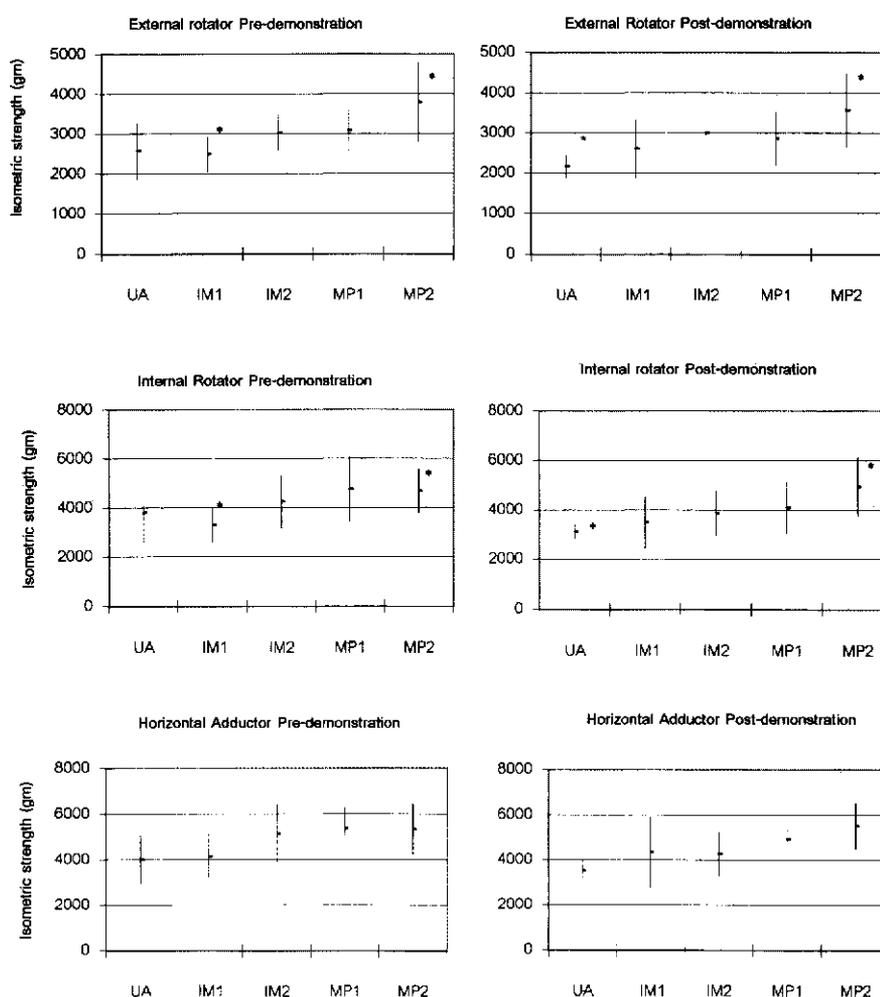


Figure 3 Mean and standard deviation of isometric muscle strength of pre- and post-demonstration A & B) External rotators, C & D) Internal rotators and E & F) Horizontal adductors

chose a mature overarm throw demonstrated higher isometric force of the external and internal rotators than those who selected an underarm or an immature overarm throw.

Relationships between muscles strength and throwing patterns: pre- and post-demonstration

The mature pattern from five trials of throwing in one individual was selected for examination to determine the relationship between throwing pattern and strength of the shoulder muscles. The results demonstrated that the strength of the shoulder muscles showed no significant changes to the pattern of throwing being selected when the effect of age was partialled out both pre and post-demonstration of the mature overarm pattern.

Discussion

Five trials of self-selected patterns of thirty-two boys throwing a ball as far as possible were analyzed. Twenty-seven subjects selected an overarm throw, and only five subjects used an underarm pattern prior to a demonstration of a more mature pattern. Classification of each throw was performed using a description of throwing maturation¹³. From 160 trials, five styles of self-selected throws have been classified with four styles related to an overarm pattern and the last being an underhand motion. For the overarm patterns, sequential motions of the upper limb and body were used as criteria for classification purposes. External and internal rotation

and horizontal adduction of the shoulder joint as well as rotation of the body with a forward weight shifting were the essential motions for categorization of a mature overarm pattern. Immature overarm throws (IM 1 and IM 2) were identified to involve a simple motion of the shoulder and the elbow joint in which subjects threw without sequential motion of the upper limb segment and no segmental rotation of the body. For example, some subjects used flexion and extension of the elbow joint or horizontal adduction of the shoulder joint for throwing. Mature overarm pattern 1 and 2 were separated from each other by forward weight shifting of the body. Boys at the age of 4-5 years old starts to develop to the mature overarm throw. Although this study did not classify a mature and an immature underarm pattern, no performances could be categorized as a skilled underhand throw¹³.

Variability of throwing patterns within subjects was also analyzed. Intrasubject variability over five throwing trials was mainly evident in those subjects using an underarm throw who switched to a more mature overarm style. Alteration of the throwing pattern arose freely during the first few trials as subjects practiced the task and became familiar with its requirements. According to the dynamic systems concept, subjects were instructed to throw as far as possible, thus the distance thrown might be one of underlying reasons for the change in the pattern employed. Furthermore, the results seem to suggest that

overarm pattern is the more stable pattern of throwing under the maximum throwing distance context.

Only the isometric strength of the external and internal rotators demonstrated a significant difference when compared among a mature overarm throw and an underarm pattern (post-demonstration) or an immature overarm pattern (pre-demonstration). The results implied that the strength of external and internal rotators might be one of the factors determined the selection of throwing pattern in young boys. However, no relationships of isometric muscle strength and the self-selected throwing patterns were identified in both pre and post-demonstration of the mature pattern. The non-significant relationship may be resulted from the small number of subject in each throwing pattern. Thus further study is required to confirm the result.

After the demonstration of mature overarm throws, some boys continued to use an immature overarm or underarm throw. Explanation was also given about the throwing action to each individual subject. Because the demonstration and instruction were presented in a short period without any practice, these boys might have had difficulty in learning from the information presented and copying the presented throwing action based on observational learning alone. Knowledge of the mature overarm pattern reduced the variability of throwing styles, especially at the age of 4-5 years old.

Conclusion

Self-selected throwing patterns of young boys as they were asked to throw a ball as far as possible were examined in this study and the relationship between these patterns and strength of the shoulder muscles was considered. The results indicated the underarm and the overarm throwing styles were the self-selected patterns under the maximum distance thrown condition. Moreover, the mature overarm throw tends to develop at the age of 4-5 years and the underarm pattern seems to be the simplest pattern when compare to the overarm style. Invariability of throwing patterns presented mainly when the underarm throw was initially selected and subjects who were 4-5 years old demonstrated a highest inter-subject variability. No significant relationship between strength of these muscle groups around the shoulder joint and self-selected throwing patterns was identified as the effect of age was partialled out. However, subjects with low isometric force of the external and internal rotators of the shoulder joint tended to throw using an underarm or an immature overarm style. These results suggest that selection of a throwing pattern under the maximum distance thrown context is dependent on age and the knowledge of the mature pattern. Other factors such as the shoulder muscles strength is possible to also contribute to the selection of particular pattern, however further studies are required.

Acknowledgment

I would like to acknowledge the help of Prof. Joan Cole of Curtin University of Technology, Perth, Western Australia in English correction and helpful comments on this manuscript.

References

1. Payne VG, Isaacs LD, editors. Human motor development: a lifespan approach. 4th ed. London: Mayfield Publishing Company; 1999.
2. McCleghlan BA, Gallabue DL. Fundamental movement: a developmental and remedial approach. Philadelphia: Saunders; 1978.
3. Butterfield SA, Loovis EM. Influence of age, sex, balance, and sport participation on development of throwing by children in grades K-8. *Percept Mot Skills* 1993;76:459-64.
4. Nelson KR, Thomas JR, Nelson JK. Longitudinal change in throwing performance: gender differences. *Res Q Exerc Sport* 1991;62:105-8.
5. Cratty BJ. Remedial motor activity for children. Philadelphia: Lea & Febiger; 1975.
6. Hurlock EB. Child development of the infant and young child. New York: McGraw-Hill Inc.; 1972.
7. Fronske H, Blakemore C, Abendroth-Smith J. The effect of critical cues on overhand throwing efficiency of elementary school children. *Phys Ed* 1997;54:88-95.
8. Burton AW, Greer NL, Wiese DM. Changes in overhand throwing pattern as a function of ball size. *Ped Exer Sci* 1992;4:50-67.
9. Southard D. Mass and velocity: control parameters for throwing patterns. *Res Q Exerc Sport* 1998;69:355-67.
10. Halverson LE, Robertson MA. The effects of instruction on overhand throwing development in children. In: Roberts G, Newell K, editors. *Psychology of motor behavior and sport*. Champaign, IL: Human Kinetics; 1979.
11. Halverson LE, Robertson MA, Safrit MJ, Roberts TW. Effects of guided practice on overhand-throw ball velocities of kindergarten children. *Res Q* 1977;48:311-8.
12. Kelso JAS. *Dynamic pattern: The self-organization of brain and behavior*. Massachusetts: The MIT Press; 1995.
13. Wickstrom RL. *Fundamental motor patterns*. 3rd ed. Philadelphia: Lea & Febiger; 1983.