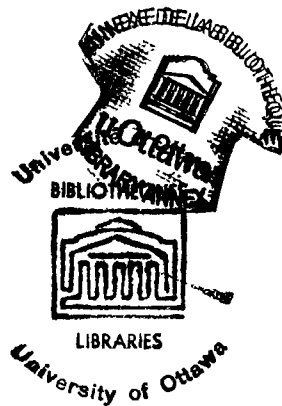


A CINEMATOGRAFICAL ANALYSIS TO DETERMINE THE EFFECTS OF AN
EXPERIMENTAL BALL ON THE MECHANICS OF THE
DRIVE-IN OVERHAND WATER POLO SHOT

by

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Thesis submitted to the School of Graduate
Studies in partial fulfillment of the Degree
of Master of Science in Kinanthropology

University of Ottawa
Ottawa, Ontario

June, 1978

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ACKNOWLEDGEMENTS

The investigator wishes to thank Dr. Robert Kerr and Mr. David Dainty for their advice and continued support throughout the study.

Also, thank you to Mr. Rezso Gallov and Mr. David 'Chick' McClintock for their time and invaluable technical assistance.

The investigator would also like to acknowledge the subjects from the Ottawa Central Sports School, the Sandy Hill Community Center, the Nepean Saturday Morning Club, the Graham Park girls, and the Ottawa Boys and Girls Club.

And finally, a very special thank you to the Ontario Water Polo Association. Without their financial support, this study would not have been possible.

DEDICATION

This study is dedicated to all the players, coaches, referees, and supporters of Water Polo who I have met over the past 12 years.

Especially to,

Dr. John Richardson, who made me realize that those 12 years have been worth everything - thank you.

ABSTRACT

The purpose of the study was to determine the effects of an experimental ball on the mechanics of the Drive-in Overhand Water Polo shot in children with no previous experience. A subproblem of the study was to determine if the transfer of skill mechanics was facilitated by the modified equipment. Two groups of subjects, aged 9 to 13 years, were given separate training periods of two weeks (6 hours). One group was

novice subjects who trained with the experimental ball were superior to those who trained with the regulation ball in terms of mechanical parameters as well as shot success. Transfer of learning was also facilitated by initially learning the skill with the modified equipment.

TABLE OF CONTENTS

	Page
LIST OF TABLES	v
LIST OF FIGURES	vi
I. INTRODUCTION	1
Statement of the problem	3
Scope of the study	3
Hypothesis	4
Limitations	5
Definition of terms	5
II. REVIEW OF LITERATURE	8
Mechanical principles of throwing and swimming	8
Overhand throw on land	8
Front crawl stroke	11
Mechanics of the drive-in overhand shot	12
Dribbling	12
Ball Handling	14
Shooting	15
Biomechanical research	17
Equipment modification	19
Summary	23
III. PROCEDURES.....	26
The subjects	26
Pretest data	26
Equipment	27
Training	29
Testing procedures	30
Test area	30
Testing	30
Analysis of Data	31
IV. ANALYSIS OF DATA	
Dribbling - phase I	33
Dribbling velocity	33
Ball location in phase I	35
Ball Handling - phase II	37
Ball handling technique	37
Ball handling time	38
Location of the ball at contact	38
Shooting - phase III	41
Shooting time	41
Linear displacement of the wrist	41
Wrist velocity at the moment of release ..	42

	Page
Ball velocity at the moment of release ...	46
Angle of the Elbow at the moment of release	46
Angle of the upper limb at release	47
Transfer of Skill Mechanics	47
Discussion of Results	49
 V. SUMMARY AND CONCLUSIONS	 52
Summary	52
Conclusions	53
Recommendations for future studies	55
 BIBLIOGRAPHY	 57
 APPENDIX	
A: Dribbling Technique, Overhand Shot, Rajki.	59
B: Axis of Rotation, Wrist, Elbow and shoulder joint, Clauser <u>et al.</u>	63
C: Training Program	66
D: Computer Programs	69
E: t-test values for Novice Experimental Group	71
F: Raw Data	73
G: Matched Group Data	79
H: Film Records	81

LIST OF TABLES

		Page
Table		
1	Phase I - Summary of Dribbling Parameters	36
2	Phase II - Summary of Ball Handling Parameters.	40
3	Displacement and Velocity Data for Figures 3 and 4	45
4	Phase III - Summary of Shooting Parameters	48

LIST OF FIGURES

		Page
Figure		
1	Filming Site	29
2	Location of Ball at Contact (Top View)	39
3	Linear Displacement of Wrist During Phase III..	43
4	Linear Velocity of Wrist During Phase III	44

CHAPTER I

INTRODUCTION

Water Polo was first developed in 1860 in England. By 1890 it was found in many parts of Europe and the United States. In 1900 it was introduced into the Olympics as an official sport, and it was shortly after this time that Water Polo came to Canada. However, it was not until the 1960's that Water Polo was being played on a nationwide basis (Richardson, 1976).

Within the last 10 years the number of participants have increased from a few hundred to a few thousand. Canadian teams have participated internationally in both mens' and womens' competitions. At the recent Olympics, Canadian men raised their standing from sixteenth to ninth in the world.

Despite this growth, which is also evident in many other countries around the world, up until 1960 there were less than 15 books written about the sport (Lambert and Goughran, 1968). This number certainly has not increased greatly over the last 18 years. Similarly, little research has been conducted on the mechanics of Water Polo skills.

Many sports are structured such that in order to fully enjoy the game, one must attain a certain level of proficiency in the skills of the sport. Those who do not

reach this level become frustrated and often leave the game. Generally, most sports are played by both children and adults and, although many sports have some rule modifications for children, very few have equipment modifications for them. For example, children who want to play volleyball usually must play with not only the regulation size ball but, also the regulation height net. It would seem more appropriate to have a proportionately smaller ball and a lower net.

A similar problem exists in Water Polo. While there are an increasing number of children exposed to the sport each year, a relatively low percentage of these children remain involved in the sport. Water Polo is an unique game which can be extremely frustrating to the novice. A major source of this frustration appears to be an inability to acquire ball handling skills using the large, regulation size ball.

A plausible solution could be to start with a smaller ball. However, the question is then raised by many coaches: 'Is he performing the skill properly?' or 'What will happen when he switches to the regulation ball?' Kerr (1976) contended that in this instance the child would not only have a greater chance at success but, it would also be highly probable that in terms of skill mechanics, the child would learn the proper mechanics earlier using the modified equipment. This supposition can be substantiated by a biomechanical analysis involving both novice and experienced children using regulation size and modified equipment.

Statement of the Problem

The purpose of this study was to determine the effects of an experimental ball on the mechanics of the Drive-in Overhand Water Polo shot in novice children. A subproblem of the study was to determine if the transfer of skill mechanics was facilitated by either regulation size or modified equipment.

Two groups of children were tested using a regulation size Water Polo ball and a lighter and smaller experimental ball. The results of the two groups were compared to a set of standards of expert children using a regulation size ball, determined in a previous study. (Pittuck, 1977).

The skill was divided into 3 phases for analysis: (1) dribbling, (2) ball handling, and (3) shooting. Within these phases the following parameters were examined: (1) dribbling velocity, (2) location of the ball during the dribbling phase, (3) ball handling time, (4) location of the ball at the moment of contact, (5) ball handling technique, (6) shooting time, (7) linear displacement of the wrist during the shooting phase, (8) wrist velocity at the moment of release, (9) angle of the elbow at the moment of release, (10) angle of the upper limb at the moment of release, and (11) ball velocity at the moment of release. Emphasis was placed on the shooting phase since it was felt that these parameters involved the more critical aspects of the skills being examined.

Scope of the Study

The films for this study were taken at the University of Ottawa swimming pool. Twenty-six children, (6 females and 20 males), between the ages of 9 and 13 years served as the subjects. None of the subjects had ever played water polo prior to the study and all could swim the front crawl at least 25 meters without stopping.

The groups were matched as to swimming speed, age, height, weight, and handspan. One group was instructed to use the regulation ball and the other was assigned to the experimental ball group. Each group was trained during 4-1½ hour sessions over a two week period in the fundamentals of Water Polo by a qualified instructor. Both groups followed the same training procedures.

Two series of trials were filmed. In the first series each group used the originally assigned equipment. During the second series, the opposite ball was used. The experimental task in both series was to dribble the ball as quickly as possible, while maintaining control, to a point 4 meters from the goal line; upon hearing a whistle the subject picked up the ball and shot it at a given target.

The films were taken with 2 stationary 16 mm movie cameras using field widths of approximately 4 meters.

Hypothesis

It was hypothesized that: (1) The novice experimental group would differ significantly from the novice regulation group in the values of the selected parameters. (2) There

would be no significant difference between the novice experimental group and the expert regulation group in the selected parameters. (3) There would be a significant difference between the novice regulation group and the expert regulation group in the values of the selected parameters.

It was further hypothesized that the transfer of skill mechanics would be facilitated by the use of a lighter and smaller ball during the initial training period.

Limitations

Since proper underwater equipment was not available, the filming was limited to above water pictures only. As a result, any underwater movements which may have influenced the performance of this skill were not considered within the scope of this study.

The parameters were selected for a mechanical analysis. Variables which were non-mechanical and which may have been affected by the modified equipment were not examined.

It should be emphasized that only one modified ball was used in the experiment, and therefore, the possible effects of other sized balls on the selected skill mechanics were not studied.

Also due to a time limitation a different instructor was used to train each of the novice groups. The instructor of the novice experimental group was the researcher of this study. However, precautions were taken to ensure that the same training protocol was followed as with the novice regulation group.

Another factor which may have affected the performances was that the subjects were performing under test conditions. This may have caused some nervousness during the testing.

Definition of Terms

The following is a list of terms which were unique to the study:

1. Test Velocity was the average velocity ($\frac{\Delta d}{\Delta t}$ meters/second), obtained by the subject over a 15 meter sprint dribble, beginning from a horizontal body position in the water.

2. Dribbling Velocity was the average velocity ($\frac{\Delta d}{\Delta t}$ meters/second), of the subject over the final 2 meters of the dribbling phase of the skill. The ear was used as the reference point since the center of gravity of the body could not be derived from the film data.

3. Ball Handling Technique was defined as that method chosen by the subject to pick the ball up from the surface of the water.

4. Ball Handling Phase was from the first film frame with the hand of the shooting arm contacting the ball to the frame directly before that in which the shooting arm began its' forward motion.

5. Ball Handling Time was the time required by the subject to complete the ball handling phase of the skill.

6. Shooting Phase was from the first indication of

any forward movement of the shooting arm to the moment of release (inclusive).

7. Shooting Time was the time required by the subject to complete the shooting phase of the skill.

8. Moment of Release was defined as that instant when the ball left the hand.

9. Angle of Release was the angle formed at the moment of release by the line through the wrist joint to the shoulder joint of the shooting arm and the line through that shoulder joint, parallel to the horizontal reference marker in the filming field.

10. Angle of the Elbow was the angle formed by the forearm and the upper arm of the shooting arm at the moment of release.

11. Target was a solid circle, 24 inches in diameter positioned in the goal area.

12. Shot Success was designated as when the ball made any contact with the target. It was recorded where the ball hit the target for each trial, (i.e. high, low, right, left or center).

13. Hand Span was measured as the maximum distance between the distal ends of the thumb and fourth digit of the shooting hand.

CHAPTER II

REVIEW OF LITERATURE

Water Polo is a relatively unresearched sport with very few biomechanical studies having been conducted. Consequently, a great deal of the literature is based on the opinions of world class players and coaches. This chapter is divided into the following sections: (1) general mechanical principles of the overhand throw on land and the front crawl stroke, (2) authoritative opinions concerning the mechanics of the overhand shot in Water Polo, (3) biomechanical research studies in the sport of Water Polo, and (4) equipment modification literature.

Mechanical Principles of Throwing and Swimming

Overhand Throw on Land. According to Broer (1973) the main objective when throwing an object is to transfer the impulse of the body to the object being thrown. Certain aspects of throwing which must be considered are distance, control, speed, and direction.

The overhand throw is used when great speed and distance are desired (Cooper, 1968). Broer (1973) stated that the true overhand throw can only be accomplished if the object is small and light enough to be grasped by the hand and controlled at a distance from the body. Broer further stated that if the object is too large, it will roll off the hand

in the back swing. Scott (1963) stated that if a ball is too large to be held by the fingers and as a result must be balanced on the open palm, it is very difficult to control at the moment of release. Throws under these conditions tend to go off on a tangent. Also, a ball that is too large can not be gripped properly. This results in a difference in the pattern of the arm action.

The actual arm motion, according to Scott (1963), should start with the body leaning well back. The elbow should lead the hand throughout the throw until the hand is by the head, at which point the hand is 'whipped' past the elbow.

Broer (1973) stated that in the overarm throw, the throwing speed is greatly affected by the number of contributing body parts. Any rotation or forward shifting, from a vertical position, of the body weight in the direction of the throw will increase the number of participating body parts and increase the length of the back swing. The result is a significant increase in the speed of the throwing hand. The speed of the hand is most crucial at a point of the throw known as the moment of release. The faster the throwing hand is moving when it releases the ball, the faster the ball will travel, if the hand is in the correct position at the moment of release.

According to Scott (1963), the distance over which the ball travels while in the hand greatly influences the speed of the ball. That is, the greater the distance over which the force is applied, the faster the ball will travel when

released. It should be noted that while these factors increase speed, they often decrease the control of the direction of the throw (Broer, 1973).

A controversy exists as to the position of the arm at the moment of release. Many studies report that the elbow is fully extended at this point, while Broer (1967) and Karpovich and Gollnick (1964), as cited in Broer(1973), reported angles at the elbow of 105° and 102° respectively. These findings were supported by Scott (1963).

Whenever an object is thrown, it is usually thrown to a target such as a catcher or a goal. The distance between the thrower and the target must be considered in executing the overhand throw. Broer (1973) stated that if the objective of the throw is distance, the angle of release should be approximately 45° . However, if the purpose is to throw the ball to the target as fast as possible, then the angle of release should be less than 45° .

Scott (1963) stated that when throwing a ball, the original inertia must be overcome. A velocity must be developed to carry it to the desired location. If the ball is light this does not present a problem. However, as the ball becomes heavier, it is more difficult to overcome the inertia. A practical example given by Scott, was in Basketball. Many children cannot produce the velocity necessary to properly throw the ball. The combination of a heavy ball and short throwing arc results in a low velocity. On land this may be overcome by switching to an underarm throw. Obviously this

is not feasible in Water Polo.

Front Crawl Stroke. Moving from land to water presents several new considerations. One should examine propulsion, resistance and stroke mechanics. The most obvious mechanical difference is that on land there is a surface which is able to support the body, while in the water this solid support is replaced by a buoyant force and water resistance. Particularly in Water Polo, the body is free floating, in that there is no contact with the bottom at any time due to the depth of the playing field.

A swimmer's speed is determined by the result of two forces - resistance and propulsion. Resistance is caused by the water the swimmer must move through and propulsion is obtained by the legs and arms (Councilman, 1968). Jensen (1970) stated that in the normal front crawl stroke the average person gains 70% of their propulsion from their arms and 30% from their legs. Councilman (1968) asserted that the main source of propulsion in the front crawl was from the arms and that in many swimmers, it was the only source.

The key to swimming fast is to reduce resistance and to increase propulsion. To decrease resistance, the swimmers must streamline their bodies. This is accomplished by swimming with the head down, turning to the side to breathe, keeping the body parallel to the surface of the water and by eliminating all actions which move the body up and down or sideways (Jensen, 1970). Councilman (1968) added that greater resistance is caused when swimmers drop their

lower body deeper into the water. The body surface is greater and hence, there is increased resistance.

Conversely, swimming speed can greatly affect the amount of resistance, as pointed out by Jensen (1970). At low speeds of 0.60 meters per second the relative resistance is greater than at higher speeds of 1.50 meters per second. This is because at the lower speeds correct horizontal body position is not maintained. Changes in swimming speed result in greatly increased resistance during acceleration. This view was also supported by Counsilman (1968).

The Mechanics of the Drive-in Overhand Shot

This section includes those references which are directly related to Water Polo.

Dribbling. Barr (1964) stated that a basic fundamental in dribbling was the position of the body. The head and shoulders should be out of the water at all times. This high body position has the effect of sinking the hips and legs. There should be no pause whatsoever at the point of hand entry and on clearing the water to begin the recovery. This continuous windmill action is necessary to maintain the high position of the upper body. The point of entry should be at shoulder width and at a distance of about eighteen inches in front of the head. The stroke recovery phase for Water Polo front crawl is much quicker than in the normal crawl stroke. If the proper body position is maintained, a wave should be formed in front of the face. The ball is kept in position by the arms, but they do not hit the ball

from side to side. This technique can be observed in Rajki (1958), Plate I, (see Appendix A).

Gallov (1974) stated that in Water Polo front crawl the arms must be bent during the stroke to help maintain the high head position. When stroking, the arms should not be placed directly in front of the head because they will impede dribbling. He further stated that novice players should be taught bilateral breathing (ie. breathing to alternate sides). He stressed the importance of the maintenance of a uniform rhythm in the high flutter kick. Contact with the ball should be made with slight touches of the shoulders, arms, forehead or nose.

Hines (1967) pointed out that in order to compensate for the sunken lower body during the dribbling phase, the kick should be slower and deeper with a bent knee action. This was supported by Liebers (1962) who stated that the bent knee brings the feet closer to the surface of the water during the upward phase of the kick.

Lambert and Gaughran (1968) asserted that the high body position was aided by hyperextending the lumbar back. This was supported by Northrip, Logan and McKinney (1974) who added that since the body must be kept at an oblique angle in the water, swimming in Water Polo was less efficient than in Competitive Swimming. They further stated that Water Polo players had a greater output of energy in moving the same distance through the water than Competitive swimmers.

Lambert and Gaughran (1968) stated that the stroke

should be short and geared for speed. They also indicated that the ball may either be carried on or pushed by the wave in front of the chest. This assertion was supported by Bland (1972). Hines (1967) suggested that for beginners who find it difficult to maintain the high body position and hence, the wave for the ball to ride on, an alternate method would be to control the ball by tapping it along with the forehead. Ideally however, the head should be free to move from side to side for the purpose of observing the surrounding field of play. This opinion was supported by both Lambert and Gaughran (1968) and Gallov (1976).

Ball Handling. Both Barr (1964) and Lambert and Gaughran (1968) agreed that picking the ball up from the surface of the water was a common problem for beginners. Lambert and Gaughran stated that the reasons for this were that novices raise the ball so rapidly that when the hand stops, the ball does not; and secondly, the beginner often fails to rotate the ball to the proper position behind and above the ear with the fingers behind the ball during the backswing. This lack of rotation results in poor throwing technique. They further claimed that the emphasis should be to get the arm and shoulder of the shooting arm out of the water. Another reason given by Barr (1964) for the difficulty in ball handling was the fact that the ball is much larger than the hand. Barr was the only authority who listed the size of the ball as a reason for difficulty encountered by beginners.

Bland (1972) listed three methods for picking up the

ball: (1) from underneath, (2) by placing the hand on the top of the ball and rotating it to a position underneath the ball, and (3) by pressing the ball down into the water and using the buoyancy to lift it off the surface. Gallov (1974) also suggested these techniques. Cutino and Bledsoe (1976) listed a fourth technique. It was to apply slight pressure to the ball from the top and then rolling the hand to underneath the ball, raise it out of the water. They stated that this method was quick, positive and efficient. All sources agreed that the ball should be picked up from underneath when first learning. Only after this has been mastered should the player attempt to pick the ball up from the top. This ensures that the concept of balancing the ball in the hand and not attempting to grip it will be learned.

Shooting. Lamberts' and Gaughrans' (1968) review of the overhand shot was quite extensive. According to them, the overhand shot is the most effective one in Water Polo. More goals are scored with it than with all others combined. It should be the first shot learned because of its' accuracy, 'power' and adaptability. It was stated that in order to execute the shot properly, the quickness of the shot and the amount of body out of the water must be emphasized. Lambert and Gaughran (1968) stated:

It should be noted that the amount of the body out of the water during the overhand shot is directly proportional to the power or speed of the throw. (p. 89).

Lambert and Gaughran equated power and speed which is not mechanically true. It was felt that they were in fact referring to the force of the overhand throw.

In the early stages of the shot the non-throwing shoulder should be turned towards the net, parallel to the line of motion of the ball. As the ball is brought forward from behind the ear, the body is rotated about the longitudinal axis. Proper rotation will increase the 'power' and speed of the shot. The upper body should gradually rotate until the shoulder line is perpendicular to the line of motion. The shooting arm continues towards the goal. The moment of release should occur when the shooting arm is almost fully extended and the last point of contact with the ball should be with the tips of the fingers. Movement of the head should be minimal to ensure better accuracy of the shot and maintenance of rhythm.

This technique was supported by Barr (1964). It was added that during the follow-through, there should be an obvious forward lean of the upper trunk, while in the initial stage of the shot there is a backward tilt of the trunk. A proper follow-through will increase the probability of the maximum acceleration of the hand occurring at the moment of release (Scott, 1963).

Cutino and Bledsoe (1976) stated that balance and body position prior to the shot were very important. The arms and shoulders should be free to move. They further stated that concentration on the target was a major factor in shooting success. Although the shooter should not stare at the specific target, all attention should be on the shot.

Gallov (1974) stated that at the moment of release,

the wrist of the shooting arm should be suddenly 'jerked' in the direction of the shot. These techniques may be observed in Rajki (1958), Plates XI and XII (see Appendix A).

Biomechanical Research

Clarys and Lewillie (1971) studied the movements of the wrist and shoulder during five Water Polo shots by means of a light trace transfer method. Subjects were members of the 1970 Belgian University Games Mens' Water Polo Team. An ordinary commercial camera was used for filming the light trace sequences. A super-8 movie camera was also used to collect subjective data. The light trace lamps were affixed to the shoulder and wrist of the throwing arm. The five shots investigated were the overhand, backhand, sidelift, push and the lay-out shot.

The light trace analysis showed that the overhand shot was a four-phase shot. The phases were designated as: (1) the pre-shot position of the shoulder and the wrist, (2) the rise of the body out of the water, (3) the forward trajectory of the wrist and shoulder, and (4) the follow-through after the release of the ball. It was also noted that during the shot the arm was flexed. At the moment of release the "arm" (elbow) was observed to be extended. The conclusions were that the distance between the shoulder and the wrist before and after the shot were approximately equal. Although the amount of shoulder displacement was less than at the wrist, the actual patterns of movement were similar.

Also, while the wrist trajectory did not change with an increase in the throwing force, the shoulder trajectory did.

In a second study by Clarys, Jiskoot and Lewillie (1973), a kinematographical, electromyographical and resistance study was made of Water Polo and Competition front crawl. The investigators proposed to study the common European theory that Water Polo stroke technique had a negative influence on Competition stroke technique. The study included an investigation of the similarities and differences of the two strokes, with emphasis on the trajectory of the elbow and wrist.

Subjects were top calibre swimmers and Water Polo players of the national division in Holland. Both 16 mm and super-8 film were used for the filming sequence. The light trace technique previously used by Clarys and Lewillie (1970) was used in the trajectory investigation. The electromyography equipment was synchronized with the cameras and the resistance tests were conducted with a tow carriage. The muscles investigated were the biceps brachii, the triceps brachii, the flexor carpi ulnaris and the brachio radialis.

The films showed that the polo stroke was characterized by a lordosis in the lumbar region and an elevation of the shoulders. The Water Polo players also showed a shorter glide period and hence, a shorter arm cycle than the Competitive swimmers as demonstrated in the light trace analysis. The actual movement patterns of the arm were similar in both stroke techniques. There were also slower swimming speeds

found in the Polo players which were attributed to the greater resistances found in these same subjects, (i.e. 6% to 45% higher resistance at 6% lower speeds in Polo Players). However, those using the Water Polo stroke had a power output of 15% to 50% higher than those using the Competitive stroke. The conclusions were that the two strokes were very similar in arm patterns and muscular activity. Also, it was concluded that Water Polo front crawl technique did not have a negative affect on the Competition front crawl.

Equipment Modification

Wright (1965) studied the relative effects of the use of light-weight equipment and heavy-weight equipment on the acquisition and retention of selected skills. Ninety-seven males and females from grades 2 and 3 were the subjects. Wright hypothesized that the learning of skills would be facilitated by the use of the lighter equipment. He further hypothesized that retention of the skills would be better in the light-weight group. Two subproblems the study proposed to investigate were the effects of the equipment modification when measured against the age and sex of the subjects.

All subjects performed a five item physical performance test consisting of standing broad jump, a bent knee sit-up, a 50 yard run, a utility throw for distance and a hand grip strength test. Using the results of this test the subjects were divided into 4 equal groups - grade 2 boys, grade 2 girls, grade 3 boys, and grade 3 girls. Within each

of the groups the subjects were again divided so that half were assigned to the light equipment and half were assigned to the heavy equipment group. It should be noted that the equipment designated as 'heavy' was actually regulation size. The light weight equipment although lighter in weight was the same size as the regulation equipment.

The four test skills used were modified bowling, basketball throw, target throw and baseball batting. The groups were given an instructional lesson in the 4 skills using the assigned equipment. The article failed to specify if all groups were instructed together and the length of the lesson. Subjects were tested 2 days after using the original equipment with which they had learned and again 9 months later.

The findings indicated that the boys performed better than the girls in all cases. The girls performed better with the lighter equipment, while the boys' performances were better with the heavy equipment. Retention of the skills were neither hindered nor facilitated by either equipment size. Wright concluded that the learning of sport-type skills by young children with limited strength may be facilitated by lighter weight equipment.

Morris (1976) reported that although children may perform successfully this does not provide information related to the mechanical efficiency of the movement pattern. He further stated that by decreasing the mechanical inefficiency one might be able to improve the child's total movement capability. He listed size, weight, texture of object, and

speed of performance as factors affecting throwing. He also suggested that manipulation of these factors might lead to changes in the mechanical performance of a child's movements.

Egstrom, Logan and Wallis (1960) investigated the acquisition of a throwing skill involving projectiles of varying weights. The purpose of the study was to determine if there were differences in the degree to which accuracy in throwing with the non-preferred hand could be developed using varying weights of projectiles. The effects of transfer of learning from the performance with a ball of one weight to the performance with a ball of another weight was also studied.

Fifty-six coed college students served as subjects for the study. They were randomly divided into 2 groups and were assigned to use one of 2 balls - 2 ounces (light) or 6½ ounces (heavy). It should be noted that both balls were 12 inches in circumference. The task was to throw the ball using an overhand throw over a horizontal pole 5 feet away at a target 10 feet on the other side of the pole. The horizontal pole was supported by 2 vertical standards and was positioned 6 inches above the subjects' height. The target, comprised of 3 concentric circles - 7, 21, and 35 inches in diameter was positioned at an angle of 30° with the ground.

A pretest of 50 trials was administered to each subject. During the following 10 days each subject had 50 trials each day using the non-preferred hand and using the assigned ball. Points were awarded for each trial. At the

end of 10 days each group was tested throwing the opposite ball with the non-preferred hand. Both groups showed significant ($p < .01$) gains in performance scores. The results indicated that subjects who practiced with the light ball were able to transfer skill better than those who practiced originally with the heavy ball.

Lindeburg and Hewitt (1966) studied the effect of a larger and heavier than regulation size basketball on shooting ability and ball handling. Twenty-six experienced male basketball players served as subjects. All subjects were tested in four different skill tests using both balls. Half of the subjects were tested using the regulation ball first and then the oversized ball and vice versa. The experimental ball was 2 ounces heavier and 1.25 inches larger than the normal ball. It was noted by the researchers that although the size was recognized by the subjects as being different, they made no comment on the weight modification.

The four skill tests were short shot, foul shot, wall passing, and obstacle dribble. A point system had been established to determine performance scores. The results showed that the experimental ball did not significantly affect the scores on the short shot, foul shot and obstacle dribble skills. It did however, have a significant effect on the passing skill. This was a negative effect since scores with the regulation ball were better. It was concluded that in general the use of an experimental ball of the nature of that used in this study would have no effect on basketball shoot-

ing and ball handling skills. The researchers noted that the study should have been repeated using a much larger ball.

A criticism of this study was the use of experienced basketball players. Since the difference in the equipment size was not sufficient to produce a change in performance, the subjects were able to adapt to the modified equipment due to their experience. Hence, not only should a larger ball have been used but, also less experienced subjects should have been tested.

Summary

The minimal amount of scientific research on this sport is evident from the review of literature. An area of controversy would appear to be concerning the angle of the elbow at the moment of release. While it is the opinion of the Water Polo authorities that the elbow is extended at this point, general authors contend that the angle of the elbow may range from 102° to 180° .

Broers' (1973) statements concerning ball size may be associated with Water Polo. According to Broer the over-hand throw can only be performed properly if the ball is small enough to be grasped by the hand. However, a basic fundamental behind Water Polo ball handling skills is an ability to balance the ball on the hand and not to grasp it. Broer further stated that if the ball is too large, it will roll off the hand in the back swing. This latter statement was supported in part by Lambert and Gaughran (1968) who stated that a common problem for novices is that they often

lose control of the ball during the back swing of the skill.

The literature indicates that these discrepancies may be due entirely to the medium in which the game is played, i.e. the principles which apply to throwing on land may differ from those which apply to throwing when the supportive base is a fluid environment.

Another area of importance was the difference between regular front crawl swimming and Water Polo front crawl, (i.e. dribbling). The principles behind the mechanics of Water Polo swimming, i.e. high upper body, sunken lower body, bent knee kicking, and short stroke turnover, are in direct contradiction to the principles of the regular crawl stroke. The basic body position for Water Polo front crawl significantly increases swimming resistance.

The aforementioned differences suggest that a possible reason for the difficulties which novice Water Polo players may have is that they attempt to swim as they normally would and throw as if performing on land.

It is evident from the equipment modification literature that changes in the equipment do affect the performances of skills. However, these effects have only been measured in terms of success and not on the mechanics of the skills. In most of the studies reviewed only the weight of the ball was changed and not the size. However, based on the instructing experience of this researcher, the most common difficulty cited by novices in Water Polo is the size of the ball.

As previously mentioned, if modified equipment is to be used with children and novices, then studies using them as

subjects must be conducted. Experienced players will have already overcome the difficulties which novices experience.

It would appear from the literature that the following are important aspects of the drive-in overhand Water Polo shot: (1) body position during the dribbling phase, (2) location of the ball during the dribbling phase, (3) the method used in picking up the ball, (4) the displacement of the wrist during the ball handling and shooting phase, (5) the velocity of the wrist at the moment of release, (6) the angle of the elbow at the moment of release, (7) the rotation of the shoulders during the ball handling and shooting phase, and, (8) the ball velocity at the moment of release.

CHAPTER III

PROCEDURES

The main purpose of this study was to determine the effects of an experimental ball on the mechanics of the Drive-in Overhand Water Polo shot in novice children.

This chapter is divided into six sections: (1) the subjects, (2) pretest data, (3) equipment, (4) training, (5) testing procedures, and (6) analysis of the data.

The Subjects

Twenty-six children, (6 females and 20 males), between the ages of 9 and 13 years served as subjects for this study. None of the subjects had ever played water polo prior to the study and all could swim the front crawl at least 25 meters without stopping. The novice regulation group (NR) had 12 males and the novice experimental group (NE) had 6 females and 8 males. The expert regulation group (ER) had 15 male subjects. All but one male subject of the NE group were right-handed.

Pretest Data

The two novice groups (NR and NE), were matched on the following criteria: age, height, weight, hand span and swimming ability. This data may be found in Appendix G. Swimming ability was determined on the basis of a timed 15

meter normal front crawl sprint.

Prior to the filming sessions, each subject swam a 15 meter sprint, dribbling the ball, to determine his test dribbling velocity. Upon hearing a whistle, the subject, beginning from a horizontal position in deep water, proceeded at maximum speed while maintaining control of the ball to a designated finish line. A second whistle was sounded at this point. The subject picked the ball up and passed it to another subject, 4 meters in front of him. Time was recorded from the first to the second whistle. This pretest was designed to simulate the actual test conditions, i.e. ball handling and passing following the dribbling phase.

In order to identify the joint centers for the analysis of the data, both shoulders, and the elbow and wrist of the shooting arm were marked with a strip of white adhesive tape prior to the practice trials. The joint centers were selected based on the bony landmarks used by Clauser, McConville, and Young, (1969) for a study in body segment parameters. The shoulder joint was marked laterally across the tip of the acromion process. The elbow joint was marked about the medial epicondyle of the humerus and the skin crease of the anterior surface of the elbow. The wrist joint was sectioned across the distal ends of the radial and ulnar styloid processes, (see Appendix B).

Equipment

A regulation size Voit Water Polo ball was used. It

was 69 cm in circumference and weighed 400 gm. The experimental ball was a Jack Watson Volleyball measuring 65 cm in circumference and weighing 270 gm.

Two stationary 16 mm cameras were used to film all trials. Both a Locam and a Bolex camera were utilized for filming the Novice Regulation Group. Due to the superiority of the motor driven Locam, it was positioned to film the more critical data, i.e. parameters specifically related to the ball handling and shooting phases. The film plane of the Locam was perpendicular to the line of motion of the experimental task. The Bolex was set perpendicular to and above the line of motion, (see figure 1). Due to the non-availability of the Locam camera at the time of the Novice Experimental groups' filming session, a second Bolex camera was used. The same frame rate, exposure, shutter etc., was used for the second Bolex as was used for the original Locam.

Black and white Kodak Tri-X Reversal film with an A.S.A. rating of 160 tungsten was used. A frame rate of 64 frames per second and 48 frames per second were used with the Locam and Bolex respectively, (the second Bolex had a frame rate of 64 frames/sec.). Lighting was provided by the indoor pool lights and 8 - 1000 watt IANE BEAM quartz lamps.

A portable scoreboard was positioned in the horizontal field for subject/trial identification. A 1 meter pole was filmed periodically by both cameras to be used in determining a conversion factor to actual size from film image size. A photo-electric cell, housed in the Locam was used

to check the frame rate of that camera and a stopwatch and a pace clock were filmed to check the Bolex.

Both a Vanguard and Lafayette motion analyzer were used to extract data from the films. The Lafayette analyzer was only used for the collection of subjective data.

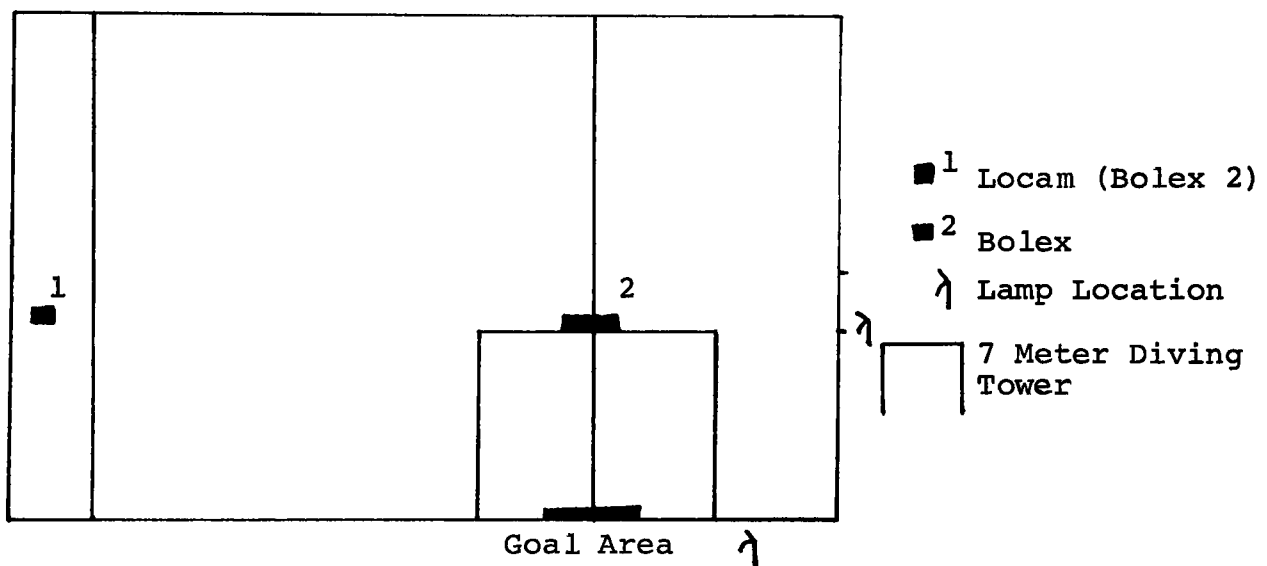


Figure 1. Filming Site

Training

One group was instructed to use the regulation ball and the other was assigned to the experimental ball group. Each group was trained separately during 4-1½ hour sessions over a two week period in the fundamentals of Water Polo by a qualified instructor. They were taught swimming, dribbling eggbeater kick, ball handling, catching, passing, and shooting.

Both groups followed the same training procedures. An outline of the training program may be found in Appendix C.

Testing Procedures

Test Area. Filming was conducted over two 4 hour periods at the University of Ottawa swimming pool. The filming area was set up as previously shown in Figure 1.

A solid wooden circle, twenty-four inches in diameter was designated as the target. It was positioned at the side of the pool in the center of the goal area. This location was chosen to ensure a more planar motion of the arm during the shot. The target was in the same position for all subjects and for all trials.

Testing. During the first film series the subjects used the originally assigned ball. Each subject was allowed up to 2 practice trials to familiarize themselves with the test conditions. For the filming sequence, the subjects were individually positioned in deep (15 feet) water with the ball, 8 meters from the goal line, in front of the target. Upon command, the subject dribbled the ball in a straight line towards the target swimming with maximum effort. A whistle was sounded when the ball reached the 4 meter line, at which point the subject picked up the ball using his preferred ball handling technique, and shot the ball at the target.

All shots were recorded. A successful shot was designated as being when the ball made any contact with the target. The site of ball contact with the target was recorded

for each trial, (i.e. right, left, center, high or low). All subjects were informed of the success criteria. Each subject was allowed a maximum of 2 practice trials with the ball that they had originally trained with and then 1 practice trial with the opposite ball.

It should be noted that practice trials were not mandatory and not all subjects chose to use them. Previous testing experience had indicated that poor performance in the practice trials could have a negative effect on the performance in the test trials.

Analysis of Data

The parameters which were selected for analysis were: (1) dribbling velocity, (2) location of the ball during the dribbling phase, (3) ball handling time, (4) location of the ball at the moment of contact, (5) ball handling technique, (6) shooting time, (7) linear displacement of the wrist during the shooting phase, (8) wrist velocity at the moment of release, (9) angle of the elbow at the moment of release, (10) angle of the upper limb at the moment of release, and (11) ball velocity at the moment of release.

The selected variables were identified from the films and then quantified numerically or evaluated qualitatively. Values for all parameters were determined for individual subjects. It should be noted that not all parameters were considered for each subject due to poor visibility in the film. Subject parameter-values were calculated as follows: If both

trials were either successful or unsuccessful, the average of two trials was used as the parameter value. If only one trial was successful, it was used as the parameter value.

Fortran computer programs (see Appendix D), were used to analyze the raw data. In those parameters involving displacement and velocity, smoothing procedures were performed. Normal filtering techniques require a minimum number of data points. The data of this study did not facilitate the use of these filtering procedures (Lanczos, 1956). All displacement data for each group was computed 3 times and then averaged as an alternate smoothing procedure. A one way analysis of variance was conducted between the three groups on the data for each parameter and where significant, submitted to a Scheffé post hoc analysis. The APL INSTA-PAK ANOVA1 was used for the computations. For the purpose of this study, significance was assessed at the .05 level. Since all subjects of the Novice Regulation and the Expert Regulation groups were male, in order to check for possible bias a student t-test was conducted between the male and female subjects of the Novice Experimental group for each of the non-subjective parameters.

CHAPTER IV

ANALYSIS OF DATA

This chapter includes the quantitative and qualitative analysis of the data. It is divided into 3 sections: (1) Dribbling, (2) Ball Handling, and (3) Shooting.

A t-test was conducted between the male and female subjects of the Novice Experimental group (NE) for the following parameters: maximum dribbling velocity, Phase I dribbling velocity, dribbling velocity as a percentage of the test velocity, shooting time, linear displacement of the wrist during the shooting phase, angle of the elbow at the moment of release, angle of the upper limb at the moment of release, and the velocity of the wrist at the moment of release. There were no significant differences found in any of the parameters except the wrist velocity at the moment of release. However, the calculated t-value was -2.302 and the critical value of t ($p < .05$) was 2.262, (see Appendix E). This supported the findings of Noble, Baker and Jones (1964) and Hodgkins (1962). Both of those studies found that at that age (10 to 12 years) there was no difference in the movement and reaction time of males and females.

Dribbling - Phase I

Dribbling Velocity. The maximum dribbling velocity (test) was calculated as the average velocity obtained by the

subject over a 15 meter sprint dribble. The Novice Regulation group (NR) mean was calculated as .87 meters per second. The group mean for the Novice Experimental (NE) subjects was .86 meters per second. For the maximum dribble ability test, one F-ratio was significant, $F(2,37) = 62.67, p < .05$. The post hoc analysis indicated that although the values for the two novice groups were not significantly different from each other, they were both significantly different from the Expert Regulation (ER) group which had a group mean of 1.35 meters per second for that parameter.

During the skill test the average velocity during Phase I for each subject was determined. It was calculated over a certain displacement measured from the film. The displacement however, varied for each subject since not all subjects began the Ball Handling phase at exactly the same location. This resulted in varying degrees of accuracy in the measurement of the variable. In order to minimize this error, trials in which less than thirty frames of Phase I were visible were not considered within the analysis.

The average velocities in Phase I were .67 meters per second and .86 meters per second for the NR group and the NE group respectively. The mean for the ER group was 1.03 meters per second. The F-value, $F(2,34) = 25.59, p < .05$, was significant and a Scheffé test indicated that there were significant differences between all three groups. It should be noted however, that the difference between the ER group and the NE group fell just within the confidence intervals.

The group means for dribbling velocity in Phase I indicated that on the average the ER subjects were performing at 79.04% of their test velocities. Nine of the subjects (N=14) swam above 75% of their maximum velocity. The NR group performed at an average of 75.55% of their test velocities and eight of the subjects (N=12) swam above 75% of their maximum. Comparatively the NE group performed at an average of 96.65% of their test velocity and all subjects swam above 80% of their maximum. This indicated that the NE subjects were not affected by the test conditions to the same degree as the NR and ER groups.

Ball Location in Phase I. It was observed that in 86.30% of their trials, the NR group did not contact the ball during this phase. The other subjects of that group made contact with the forearms, chin and/or shoulders. In 93.75% of all NE group trials no contact was made. It was also observed in the NR group that of the 86.30% where no ball contact was made, in 50% of the cases, these subjects dribbled excessively far from the face. Hence, they gave up the protection of the ball for a non-contact style of dribbling. This dribbling technique is characteristic of novices and is considered to be "incorrect" (Lambert and Gaughran, 1968; Gallov, 1976; Hines, 1968). This characteristic was not found in the NE group.

In the ER group there was no contact made in 71.43% of the trials. Although this was lower than the two novice groups, the reason for the contact must be considered. It

Table 1

Phase I - Summary of Dribbling Parameters

PARAMETER	EXPERT REGULATION	NOVICE REGULATION	NOVICE EXPERIMENTAL	d.f.	F-Value
Maximum Drib- bling Velocity (test) m/s	N=14 X=1.35m/s SD=.15	N=12 X=.87m/s SD=.12	N=14 X=.86 m/s SD=.11	2.37	62.67*
Dribbling Velocity PI m/s	N=13 X=1.03 m/s SD=.13	N=12 X=.67m/s SD=.15	N=12 X=.86m/s SD=.10	2.34	25.59*
Location of Ball During PI	71.43% No Contact 28.57% No Contact #Trials = 28	86.3% N.C. 13.7% Contact # Trials = 22	93.75% N.C. 6.25% Contact # Trials = 16	NA	NA

* p < .05

should be noted that to be classified as having made contact with the ball, the subject had only to touch the ball once. When the expert subjects touched the ball it was to correct the position of the ball. Usually it moved the ball laterally to in front of the face. However, when the novice subjects touched the ball it was for the purpose of moving the ball forward. It was in fact part of their dribbling technique. These results support the statements of Barr (1964) and Gallov (1974) who asserted that although contact with the ball while dribbling should be kept to a minimum, adjustments in the positioning of the ball could be made with touches of the shoulders, arms, forehand or nose.

The results of the Phase I parameters indicated that under skill test conditions the smaller and lighter ball facilitated higher dribbling velocities in the novice players. The regulation ball prompted a poorer technique of dribbling in novices and in a game situation those players (NR) would tend to lose the ball more often than the other novice subjects (NE).

Ball Handling - Phase II

Ball Handling Technique. It was observed that 87.50% of the NR group used the underneath method as compared to 21.40% in the ER group, see Table 2. All subjects of the NE group used the underneath technique. It should be noted that the experts had been trained to use the top and roll technique and that although both techniques were taught to the novice groups, the underneath method was

stressed by the instructors. Two subjects of the NR group did attempt the top and roll method and both were successful.

Another point which was noted during this section of the analysis was that in the NR group, there more unsuccessful trials due to ball handling difficulty than in the NE group, (NR-4, NE-1). This observation supported the opinions of Barr (1964) and Lambert and Gaughran (1968) who all agreed that picking the regulation ball up was a common problem for beginners. However, the results indicated that for those subjects who trained initially with the experimental ball, ball handling was not a problem.

Ball Handling Time. It was not possible to determine the ball handling time of the novice groups since the exact moment of contact with the ball was not visible due to the preference of these subjects to use the underneath method of picking up the ball. The mean value for the ER group was 1.14 seconds. Although not quantified within the scope of this study, it was observed that the Ball Handling phase was in fact 2 sub-phases: (1) picking the ball up, and (2) the back swing. These sub-phases were observed to have occurred only in the ER group and not in either of the novice groups. Furthermore, it was noted that some of the subjects of the expert group allotted a greater percentage of their total Phase II time to one of the two sub-phases.

Location of the Ball at Contact. There were 3 distinct areas used by the subjects: (1) in front and perpendicular to the shooting shoulder, (2) in front and outside

(TOP VIEW)

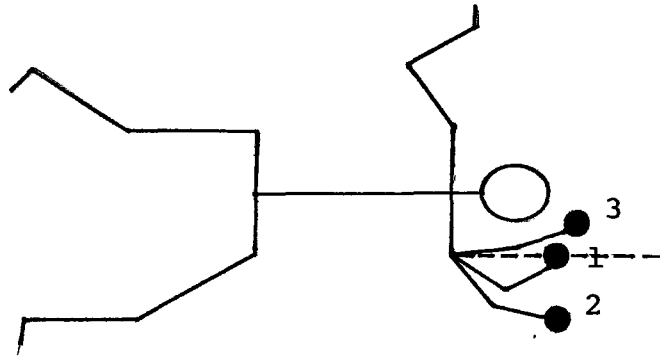


Figure 2. Location of the Ball at Contact

Table 2
Phase II - Summary of Ball Handling Parameters

PARAMETER	EXPERT REGULATION	NOVICE REGULATION	NOVICE EXPERIMENTAL	d.f.	F-value
Ball Handling Time	N=13 \bar{X} =1.14s SD=.17	Underneath method	Underneath method	NA	NA
Ball Handling Technique	78.6% Top & Roll 21.4% Under- neath	12.5% T & R 87.5% Under- neath	100% Underneath	NA	NA
Location of Ball at Contact	1) 23.08% 2) 46.15% 3) 30.77%	1) 29.2%* 2) 41.7% 3) 8.39%	1) 18.75% 2) 75.00% 3) 6.25%	NA	NA

* 20.5% Not Visible in NR group.

the perpendicular line to the shooting shoulder, and (3) inside the perpendicular line to the shooting shoulder, (see figure 2). All groups preferred location 2 - in front and outside the perpendicular line to the shooting shoulder. However, it should be noted that 20.50% of the trials were not visible for this parameter in the NR group.

Shooting - Phase III

Shooting Time. The average shooting time for each of the three groups was .22 seconds. There was also little difference in the standard deviations of the three groups. They were .04, .05, and .07 for the ER, NR, and NE groups respectively.

Linear Displacement of the Wrist. This variable was computed with data extracted from the horizontal camera film (i.e. Locam and Bolex 2). It was measured as linear displacement when in fact the motion was angular in nature. However, to ensure a more planar motion of the arm during the shooting phase, the target was positioned in the centre of the net area. Also, the target was in the same location for all groups.

The mean displacement for the NR group was .61 meters and .71 meters for the NE group. The F-value was significant, $F(2,32)=6.45$, $p < .05$. Post hoc analysis of the linear displacement data revealed that there was a significant difference between the NR group and the ER group but, not between the ER group and the NE group, or the two novice groups.

Since there was no difference in the shooting times of the groups, this indicated that the difference between

the groups was in the speed at which the arm was travelling in the shooting phase.

One subject was selected from each group as being representative of the average of their respective group. The results are illustrated in Figures 3 and 4. Figure 3 represents the linear displacement of the wrist during the shooting phase. A similarity in the patterns can be observed between the NE and the ER groups. Figure 4 illustrates the velocity of the wrist during Phase III. Again, there is a similarity in the patterns of the NE and ER groups. The similarity between the displacement and velocity patterns of the individual groups was due to the use of interval displacements. All three subjects obtained their maximum velocity prior to the moment of release. However, the NR subject had a greater decrease in his wrist velocity at the moment of release than the other subjects.

It should be noted that the limited number of data points in the expert group data were due to blurring of the motion on the film. This was caused by a combination of low camera speed and a high velocity of the wrist. However, all displacement data for each group was computed three times and then averaged as a smoothing procedure. The accompanying data for Figures 3 and 4 may be found in Table 3.

Wrist Velocity at the Moment of Release. Wrist velocity was a significant variable, $F(2,33)=26.56$, $p < .05$. Post hoc analysis indicated there was a significant difference between both of the novice groups and the expert group. Although there was no significant difference between the two

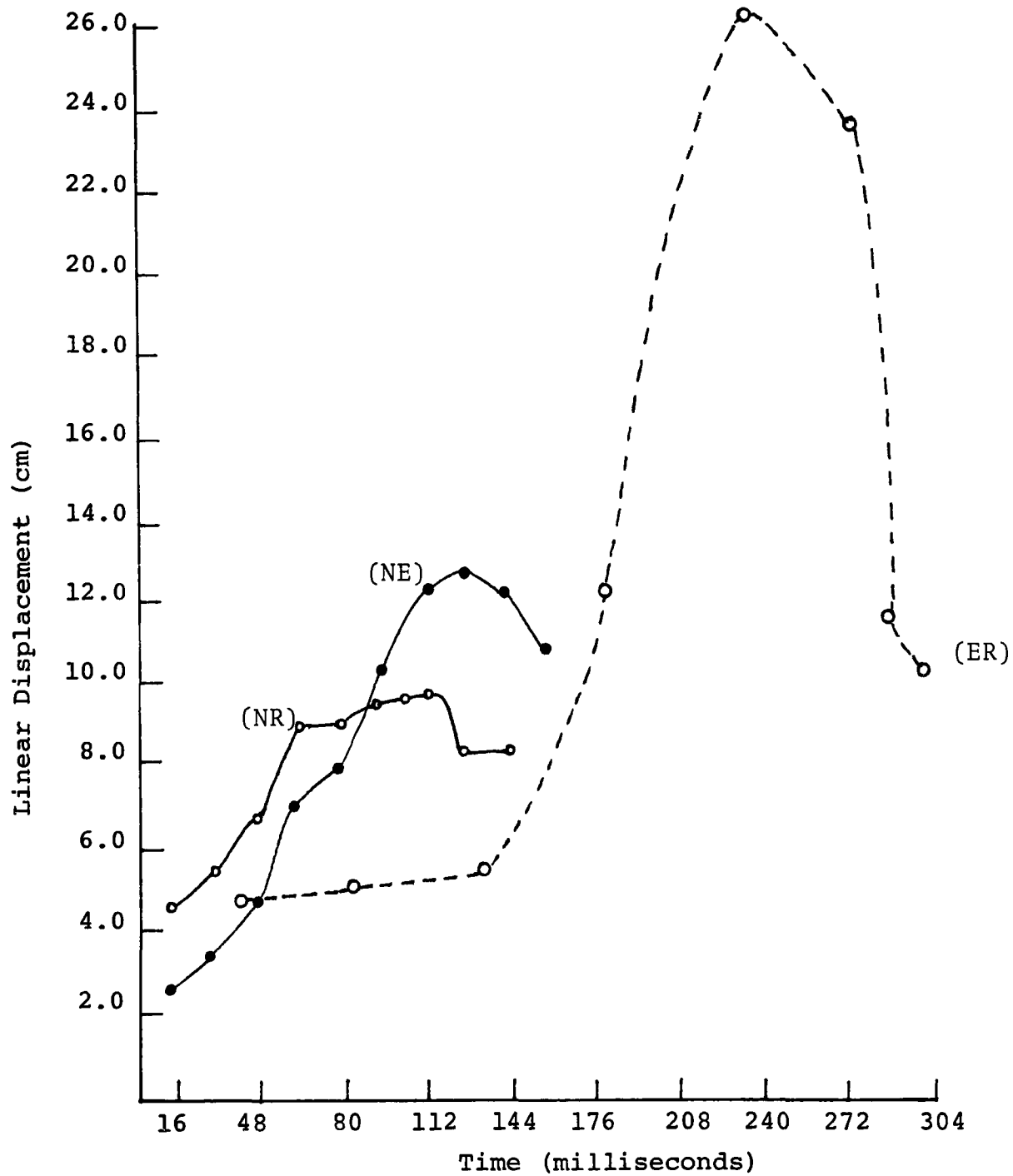


Figure 3. Linear Displacement of Wrist During Phase III.

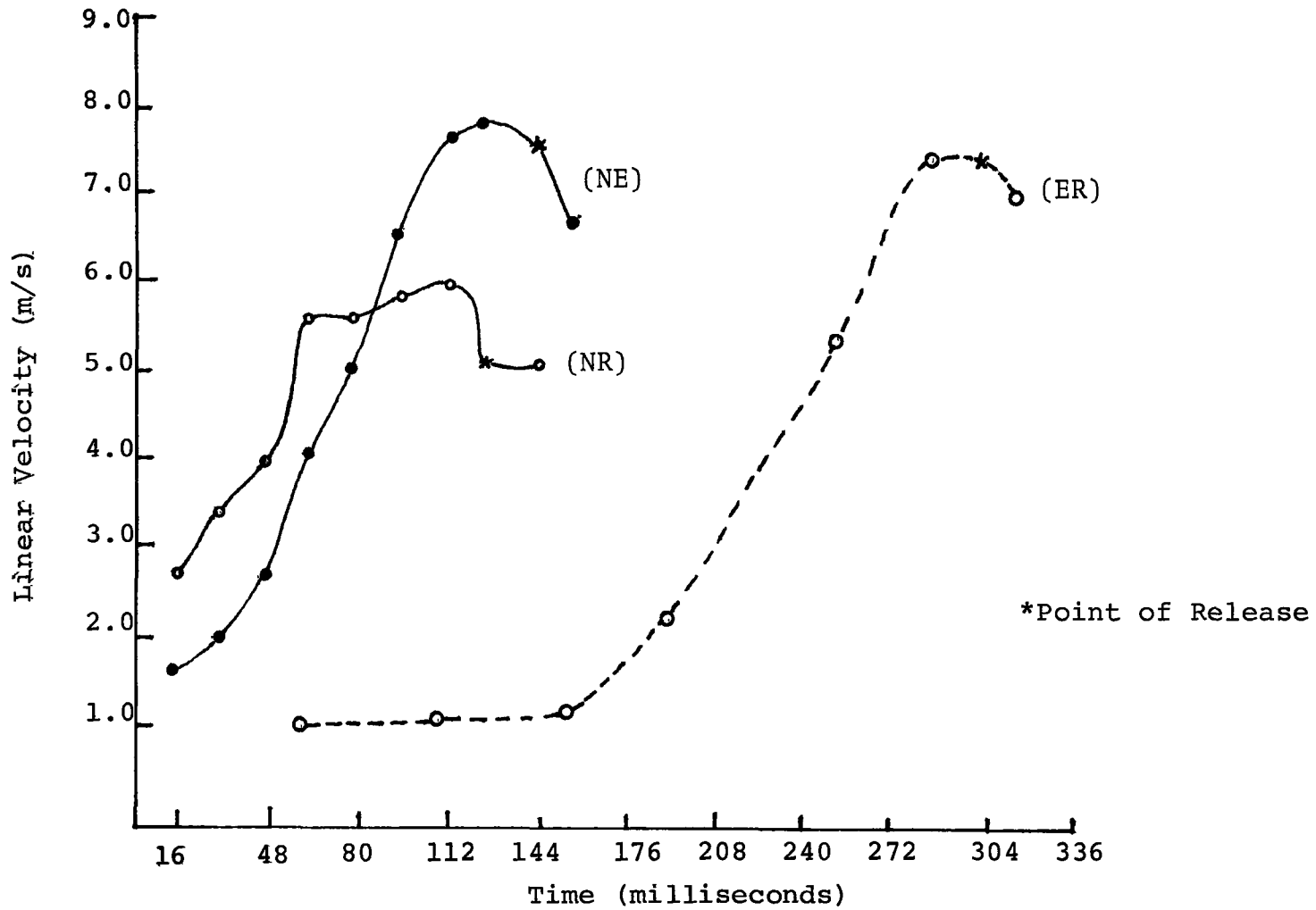


Figure 4. Linear Velocity of Wrist During Phase III

Table 3
Displacement and Velocity Data for Figures 3 and 4

Interval	EXPERT REGULATION		NOVICE REGULATION		NOVICE EXPERIMENTAL	
	\vec{d}	\vec{v}	\vec{d}	\vec{v}	\vec{d}	\vec{v}
4	4.88 cm	1.00m/s	1 4.32 cm	2.69m/s	1 2.64 cm	1.65m/s
7	5.29	1.10	2 5.51	3.44	2 3.27	2.04
10	5.51	1.15	3 6.42	4.00	3 4.33	2.70
12	12.27	2.26	4 8.92	5.56	4 6.50	4.07
16	26.27	5.47	5 8.99	5.63	5 8.07	5.05
18	23.96	7.49	6 9.39	5.88	6 10.50	6.56
19	11.94	7.46*	7 9.57	6.00	7 12.37	7.73
20	11.24	7.03	8 8.23	5.13*	8 12.67	7.92
			9 8.24	5.13	9 12.26	7.67*
					10 10.77	6.73

* Moment of Release

novice groups, the NE group did have a greater mean wrist velocity (5.62 meters per second) than the NR group, (4.45 meters per second). The former also had a greater mean linear displacement in the wrist during the shooting phase. The ER group had a mean wrist velocity 8.14 meters per second.

Ball Velocity at the Moment of Release. The average velocity of the NR and NE groups were 7.05 meters per second and 7.58 meters per second respectively. The mean for the ER group was 12.53 meters per second, the resultant F-value was significant, $F(2,26)=57.67$, $p < .05$. The post hoc analysis indicated that there was no significant difference between the two novice groups but, that there was a significant difference between each novice group and the expert group. The results of the two previous parameters - wrist velocity and linear displacement of the wrist, indicated that the NE subjects theoretically should have obtained greater ball velocities, (Scott, 1963).

Angle of the Elbow at the Moment of Release. This was the angle formed by the forearm and the upper arm of the shooting arm at the moment of release. The average value for the NR group was 136.90° . The NE group mean was 119.20° and the ER group had a mean of 141.3° . The analysis of variance was significant, $F(2,25)=3.87$, $p < .05$. Post hoc analysis indicated that the only significant difference was between the NE group and the ER group.

In the analysis of the angle measurements, the amount of usable data for the two novice groups was extremely small. Also, although it was recorded as to where the ball hit the

target (i.e. high, low, right, left or center) the visibility of this variable on the films was poor. This resulted in a low number of data values. As a result the analysis could not be broken down into "hit-area" as was originally proposed.

Angle of the Upper Limb at Release. This angle was measured as the angle formed at the moment of release by the line through the wrist joint to the joint of the shooting shoulder (i.e. the upper limb), and the line through that shoulder parallel to the horizontal reference marker. The mean values were 52.28° , 45.52° and 53.52° for NR, NE and ER groups respectively. None of the values were significantly different from each other. However, there was a high standard deviation in the NE group (10.15) and the NR group (9.54). The standard deviation of the ER group was 6.27.

Transfer of Skill Mechanics

It was originally proposed that a sub-problem of the study would be to determine if the transfer of skill mechanics was facilitated by either the regulation size or modified equipment. However, due to poor quality film a complete analysis could not be computed with the data of the two novice groups.

A total of 17 shots were taken by the novice experimental group with the regulation ball. All but 4 (23.5%) were successful shots. The novice regulation group missed 9 of their total 24 shots (33.3%) with the regulation ball. They were also unsuccessful in 6 of 17 shots (35%) with the

Table 4

Phase III - Summary of Shooting Parameters

PARAMETER	EXPERT REGULATION	NOVICE REGULATION	NOVICE EXPERIMENTAL	d.f.	f-value
Shooting Time	N=14 \bar{X} =.22s SD=.04	N=11 \bar{X} =.22s SD=.05	N=13 \bar{X} =.22s SD=.07	NA	NA
Linear Dis- placement of Wrist During P3	N=13 \bar{X} =82.91cm SD=11.71	N=11 \bar{X} =61.19cm SD=1.09	N=11 \bar{X} =70.54cm SD=1.46	2.32	6.45*
Wrist Velocity at Moment of Release	N=14 \bar{X} =8.14m/s SD=1.32	N=11 \bar{X} =4.45m/s SD=1.09	N=11 \bar{X} =5.62m/s SD=1.46	2.33	26.56*
Angle of El- bow at Re- lease	N=14 \bar{X} =141.3° SD=12.52	N=8 \bar{X} =136.9° SD=20.99	N=6 \bar{X} =119.2° SD=17.87	2.25	3.87*
Angle of Up- per Limb at Release	N=14 \bar{X} =53.52° SD=6.27	N=8 \bar{X} =52.28° SD=9.54	N=6 \bar{X} =45.52° SD=10.15	2.25	2.08
Ball Velocity at Moment of Release	N=13 \bar{X} =12.53m/s SD=1.55	N=10 \bar{X} =7.05m/s SD=1.11	N \bar{X} =7.58m/s SD=1.038	2.26	57.67*

* p < .05

smaller, lighter ball, whereas the NE group were unsuccessful in 4 of 31 (12.9%) shots with that ball.

It should also be noted that when questioned, all novice subjects reported that they preferred the smaller and lighter ball. Unlike the study of Lindeburg and Hewitt (1966), all subjects (novice) noted both the weight and size modification of the ball.

Discussion of Results

The results of the study indicate that the expert subjects were superior to the two novice groups investigated for all parameters studied. An initial concern of the investigator was that the novice subjects may have been affected by the test conditions, whereas the expert subjects had been involved in the production of a film previously. Hence, a comparison of the 3 groups may have been unfair. The results though indicated that the novice subjects were not negatively affected by the testing situation.

The dribbling techniques exhibited by the NE group were superior to those of the NR group. The results supported the statements of Lambert and Gaughran (1968), Gallov (1976) and Hines (1967). All those authorities stated that non-contract dribbling was preferable.

It was observed that many of the unsuccessful shots in the novice groups were caused by difficulties encountered in the ball handling phase of the skill. These difficulties were incurred at one of two points in the phase. Subjects were either unable to initially raise the ball from the surface of the water or they lost the ball in the back

swing. A possible reason for this may have been that the ball was proportionately too large for the hand (Barr, 1964), or that the subject was moving the ball too quickly through the back swing (Lambert and Gaughran, 1968). Conversely, unsuccessful shots in the ER group were observed to be due to poor shooting techniques.

As was recommended by all authorities, the underneath method of picking up the ball was stressed by the instructors. A concern of the investigator was that if the ball was reduced too much in size, the subjects would tend to grip it, as opposed to balancing it in the hand. However, the results of the ball handling technique parameter indicated that subjects were not trying to pick the ball out of the water, but rather lift it out.

It was also shown that although the same ball handling technique and location at the moment of contact were used by both novice groups, there were less unsuccessful shots in the NE group, (i.e. NE-4, NR-9).

The results indicated that those subjects using a lighter and smaller ball were able to maintain a greater wrist velocity throughout Phase III over a greater displacement, (i.e. longer back swing). This combination according to Scott (1963) would greatly increase the ball velocity at the moment of release. Although the NE subjects did have a slightly higher mean velocity than the NR group, it was felt that the lack of significance in the differences of the groups was caused by the small sample size.

Regarding the angle parameters the results do not

support the statements of Lambert and Gaughran (1968) who asserted that the arm should be extended at release. There did not appear to be any relationship between the wrist velocity at the moment of release and the angle of the elbow at release. However, in all 3 groups the highest wrist velocity obtained was by a subject with a below group average elbow release angle. Within each group there were various combinations of the 2 parametric values, (i.e. high velocity - low angle, high velocity - high angle, etc.)

It would appear from the results that for the distance over which the ball was being thrown for the purposes of this study, and considering that a target was used, that the angle of the elbow and of the upper limb at the moment of release were not of critical importance. It was felt that the variance found in the angle measurements was due to the size of the target. A smaller target would have yielded a more consistent set of results. However, it might also have increased the psychological pressure in the performance of the novice subjects.

It was also observed that not only was the novice experimental group more successful with the ball they had been trained with, they also had a higher success rate when they transferred to the opposite ball. It must be stressed though, that this does not confirm the transfer of specific skill mechanics.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to determine the effect of an experimental ball on the mechanics of the Drive-in Overhand Water Polo shot in novice children using cinematographical techniques. A sub problem was to determine if the transfer of skill mechanics was facilitated by either regulation size or modified equipment.

It was hypothesized that: (1) The novice experimental group would differ significantly from the novice regulation group in the values of the selected parameters. (2) There would be no significant difference between the novice experimental group and the expert regulation group in the selected parameters. (3) There would be a significant difference between the novice regulation group and the expert regulation group in the values of the selected parameters.

It was further hypothesized that the transfer of skill mechanics would be facilitated by the use of a lighter and smaller ball during the initial training period.

Twenty-six children (6 females and 20 males), between the ages of 9 and 13 years served as the subjects. They were divided into two groups and tested using a regulation size Water Polo ball and a lighter and smaller experimental ball. The results of the two groups were compared to a set of standards of expert children using a regulation ball, determined

in a previous study, (Pittuck, 1977).

The experimental task was to dribble the ball as quickly as possible, while maintaining control, to a point 4 meters from the goal line; upon hearing a whistle the subject picked up the ball and shot it at a given target.

Two stationary 16 mm cameras - a Locam and a Bolex set at 64 frames per second and 48 frames per second respectively were used to film the subjects.¹ Both a Vanguard and a Lafayette motion analyzer were used to extract data from the film. Computations were made using a Fortran program and an APL INSTAPAK, (ANOVA1) on an IBM 360 computer.

The parameters studied were (1) dribbling velocity, (2) location of the ball during the dribbling phase, (3) ball handling time, (4) location of the ball at the moment of contact, (5) ball handling technique, (6) shooting time, (7) linear displacement of the wrist during the shooting phase, (8) wrist velocity at the moment of release, (9) angle of the elbow at the moment of release, (10) angle of the upper limb at the moment of release, and (11) ball velocity at the moment of release.

Conclusions

In relation to the original hypotheses, it was found that: 1. The NE group differed significantly from the NR group only in the dribbling velocity (PI) parameter. Although not significant, they also performed superiorly to the NR subjects in the linear displacement of the wrist, wrist velocity and ball velocity at the moment of release parameters.

¹ A second Bolex camera was used when filming the NE group.

Subjective analysis indicated that the NE group also exhibited superior dribbling and ball handling techniques to the NR group.

2. The NE group did not differ significantly from the ER group in the wrist displacement parameter. They also performed closer to the ER group mean than the NR group in the dribbling velocity (PI), wrist velocity and ball velocity at the moment of release parameters.

3. The NR group differed significantly from the ER group in the dribbling velocity (PI), wrist displacement, wrist velocity and ball velocity parameters.

Furthermore, the results suggested that the transfer of skill mechanics may have been facilitated by the use of a lighter and smaller ball during the initial training.

Within the limitations of this study, the following conclusions were made in regard to initial training with a smaller and lighter ball:

1. The use of the experimental ball facilitated higher mean dribbling velocities and a superior technique of dribbling in novices.
2. Those subjects who were initially trained with the experimental ball displayed superior ball handling skills to those subjects who were trained with the regulation ball.
3. The use of the experimental ball neither facilitated nor hindered the time required by the novice subjects to complete the shooting phase.

4. Initial training with the experimental ball prompted both a greater mean wrist velocity and ball velocity at the moment of release.
5. The experimental ball facilitated a greater mean displacement of the wrist during the shooting phase, (i.e. increased back swing).
6. Those subjects who were initially trained with the smaller and lighter ball demonstrated greater success in performance when they performed the skill using either ball.

Within the scope of this study it was concluded that for novice children between the ages of 9 and 13 years, the use of a smaller and lighter ball for initial training did promote superior skill mechanics in the dribbling, ball handling and shooting phases of the Drive-in Overhand Water Polo Shot.

Recommendations for Future Studies

Based on the findings of this study the following recommendations are made:

- (1) In order to ensure a better quality of film for analysis, increased lighting should be used to allow for a frame rate of at least 100 frames per second.
- (2) Underwater cameras must be used to investigate any underwater movements which affect the performance of the skill.
- (3) Larger sample sizes should be used to strengthen the findings of the present and future studies.

(4) Further investigation should be made into the transfer of skill mechanics where modified equipment is used.

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APPENDIX A

Dribbling Technique, Overhand Shot

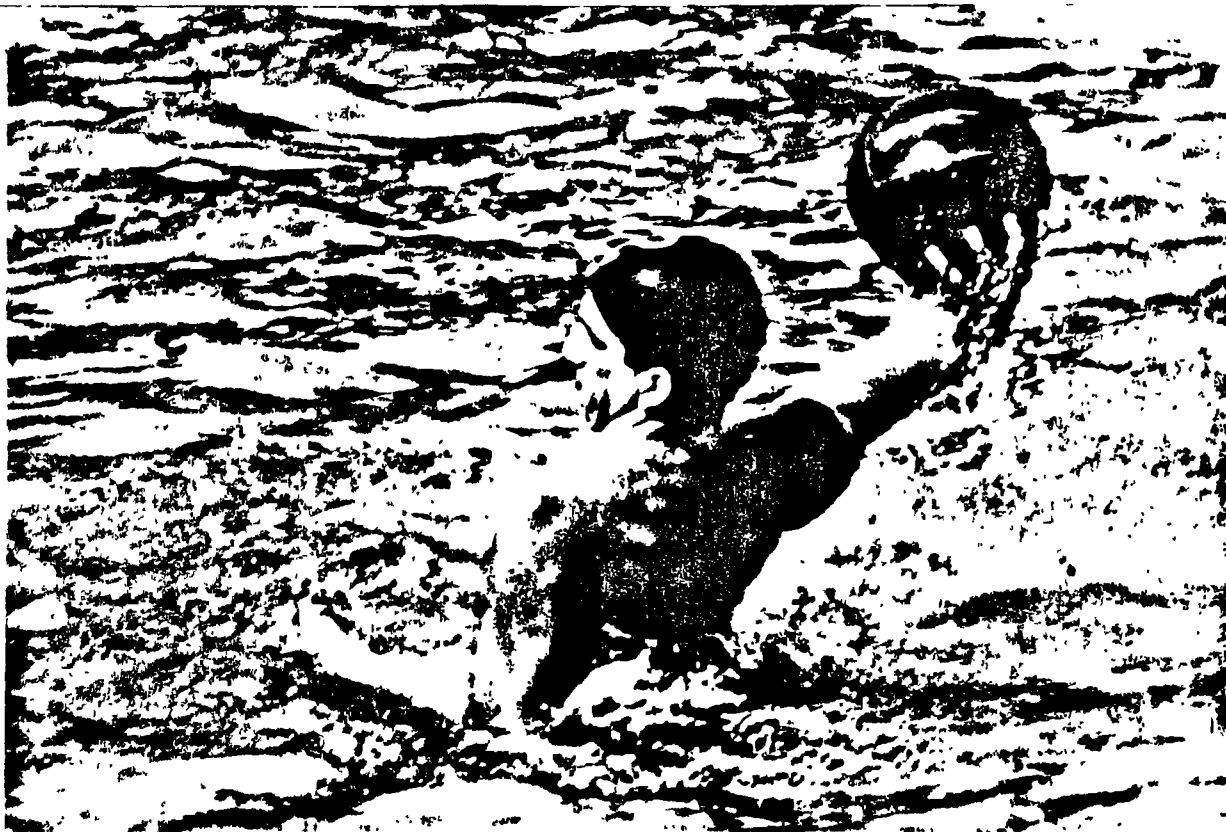


OVERHAND SHOT

PLATE XII

Rajki Béla, 1958

APPENDIX A



OVERHAND SHOT

PLATE XI

Rajki Béla, 1958

APPENDIX A



DRIBBLING

PLATE I

Rajki Béla, 1958

APPENDIX B

Axis of Rotation for Shoulder
Elbow and Wrist

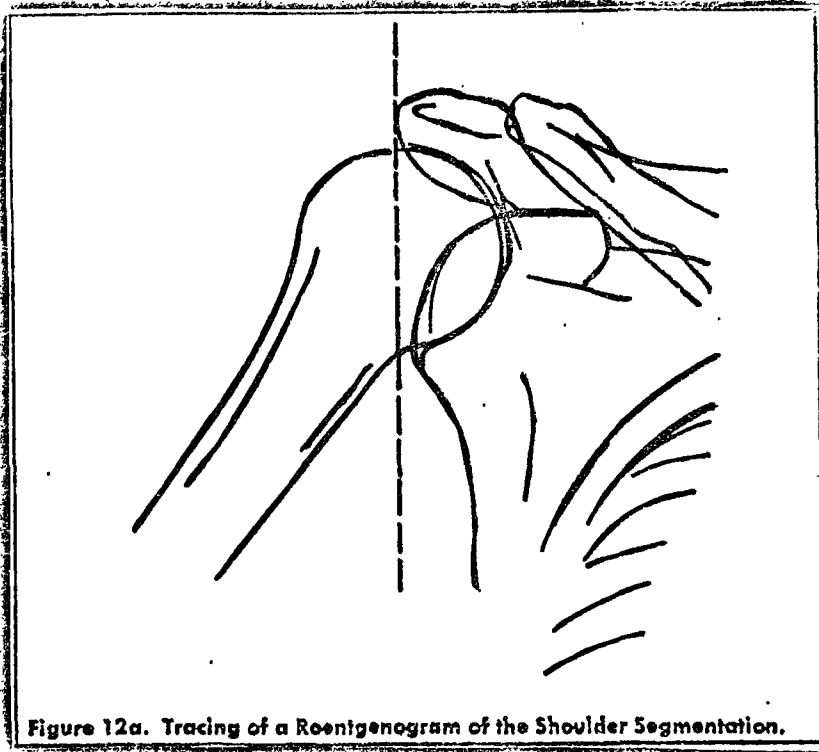


Figure 12a. Tracing of a Roentgenogram of the Shoulder Segmentation.

AXIS OF ROTATION OF SHOULDER JOINT

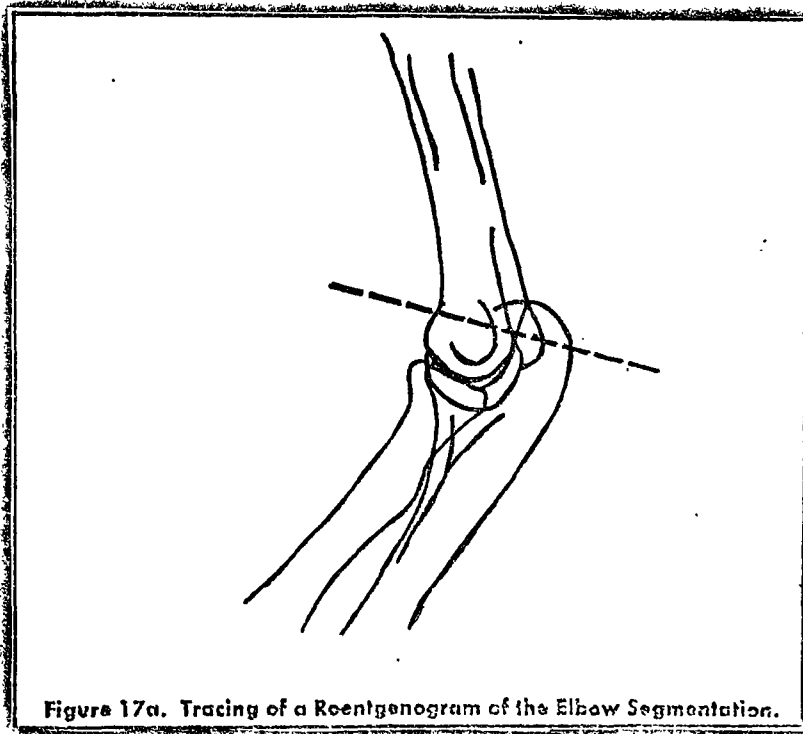
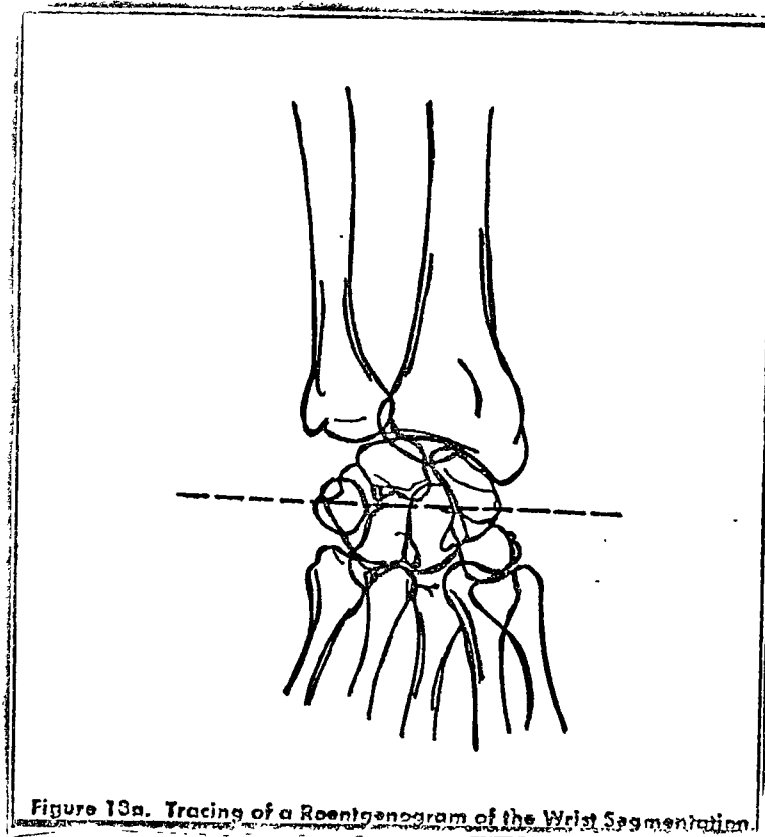


Figure 17a. Tracing of a Roentgenogram of the Elbow Segmentation.

AXIS OF ROTATION OF ELBOW JOINT



AXIS OF ROTATION OF WRIST JOINT

CLAUSER et al., 1969

APPENDIX C

Training Program

Appendix C

TRAINING PROGRAM

DAY I

- (1) Swimming for Water Polo: (i) Head-up Front Crawl
(ii) Head-up Backstroke
(iii) Head-up Breaststroke
- (2) Stop & Starts - Ready Position
- (3) Dribbling: (i) Push Dribble
(ii) Straight Dribble
- (4) Ball Handling (i) Underneath Pickup
(ii) Top & Roll Pickup
- (5) Passing: Wet

DAY II

- (1) Review of Day I
- (2) Passing - Shallow End
- (3) Egg Beater Kick
- (4) Passing - using Egg Beater
- (5) Forehand Shot
- (6) Skill Test Practice

DAY III

- (1) Review of Days I & II
- (2) Widths of Dribbling, Swimming, Shooting Simulation
- (3) Water Walking
- (4) Skill Test Practice
- (5) Game

DAY IV

- (1) Review of Strokes, Dribbling, Rollovers
- (2) Passing
- (3) Shooting
- (4) Test Practice
- (5) Game

DAY V

Filming

APPENDIX D

Computer Program

Fortran Program.

Linear Wrist Displacement

```
1   DIMENSION WRTX(19,22),WRTY(19,22)
2   REAL Z
3   READ,Z
4   DO 25 J=1,19
5   PRINT,J
6   DO 10 I=1,22
7 10  READ (5,15) WRTX(J,I),WRTY(J,I)
8 15  FORMAT (2F6,4)
9   WDIS=0.
10  DO 20 K=1,21
11  A=0.
12  A=A+SQRT((WRTX(J,K+1)-WRTX(J,K))**2+(WRTY(J,K+1)-
13  WRTY(J,K))**2)
13  A = (A*2.54)*Z
14  WRITE (6,16) K,A
15 16  FORMAT(2X,'INTERVAL',I2,5X,3F7.4)
16 20  WDIS = WDIS + A
17  WRITE(6,17) J,WDIS
18 17  FORMAT(2X,'SUBJECT',I2,5X,'WRIST=',F9.5)
19 25  CONTINUE
20  PRINT,Z
21  STOP
22  END
```

APPENDIX E

t-test Results

Appendix E

t-test Results


Parameter	\bar{X}_F	\bar{X}_M	df.	t-ratio
Maximum Dribbling Velocity (Test)	.81	.90	12	-1.328
Dribbling Velocity (Phase I)	.84	.86	10	-.323
Dribbling Velocity as % of Maximum	97.04	96.37	10	.101
Shooting Time	.20	.23	11	-.637
Linear Displacement of Wrist (Phase III)	60.40	78.99	9	-1.542
Angle of Elbow at Release	127.80	110.50	4	1.250
Angle of Upper Limb at Release	45.08	45.96	4	-0.95
Wrist Velocity at Release	4.69	6.40	9	-2.302*

* $t(9)=2.262$, $p<.05$
 $p<.05$

APPENDIX F

Raw Data

PARAMETER	EXPERT REGULATION		NOVICE REGULATION		NOVICE EXPERIMENTAL	
Maximum Dribbling Velocity (Test)	1.40m/s 1.41 1.04 1.21 1.42 1.17 1.21	1.30 1.57 1.42 1.35 1.50 1.53 1.30	.93m/s .85 .73 .86 1.17 .98	.72 .83 .94 .77 .83 .80	.85 .80 1.05 .85 .98 .76 .80	.91 .98 .91 .80 .68 .72 - .98 N=14
Dribbling Velocity (Pl)	1.26m/s 1.08 .92 1.11 1.01 1.04 .80	.86 1.20 1.10 1.04 1.04 - .99 N=13	1.0 .71 .59 .70 .88 .62	.59 .50 .75 .48 .56 .60 N=12	.83 .89 .84 .84 1.05 .84 .80	.80 .86 .85 .65 - - - 1.02 N=12
Dribbling as % Max. (Vel)	90.13% 76.22 88.43 92.03 73.63 88.49 76.12 66.51	76.29 84.30 73.21 77.33 64.77 N=13	107.53% 83.53 80.82 81.40 75.21 63.27	81.94 60.24 79.79 62.34 67.47 75.00 N=12	97.65% 111.25 80.00 98.82 107.14 110.53 100.00	87.91 87.76 93.41 81.25 - - - 104.08 N=12

PARAMETER	EXPERT REGULATION	NOVICE REGULATION	NOVICE EXPERIMENTAL
Ball Handling Time	1.02sec. .88 1.29 1.17 1.25 .85 1.05 1.12 1.23 .82 .93 .98 1.26 N=13	: since underneath - not visible at exact moment of contact 1.42 sec. 1.01	: since underneath - not visible at exact moment of contact
Location at Contact	N=  23.08% (1) 46.15% (2) 30.77% (3)	N=24 (all trials) 29.2% (1) 41.7% (2) 8.3% (3) 20.5% Not visible	18.75% (1) 75% (2) 6.25% (3)
Ball Handling Technique	N= 78.6% - Top & Roll Tech. 21.4% - Underneath	N=24 (all trials) 12.5% - Top & Roll Tech. 87.5% - Underneath	all trials 100% underneath

PARAMETER	EXPERT REGULATION		NOVICE REGULATION		NOVICE EXPERIMENTAL	
Shooting Time	.25sec.	.25	.18sec.	.18	.16	.22
	.27	.22	.14	.28	.17	.25
	.19	.17	.23	.18	.18	.26
	.15	.20	.22	.29	.18	.13
	.21	.25	.21	.28	.35	.14
	.18	.30	.24		.31	.22
	.17	.21			.24	
			N=14	N=11		N=13
Linear Disp. of Wrist During P3	90.15cm	74.53	71.13cm	62.43	52.21	
	67.62	90.20	57.23	59.84	41.24	
	83.31	99.52	61.01		-	
	69.46	83.11	52.33		58.06	
	80.44	103.75	60.15		68.50	
	73.10	92.23	59.61		99.59	
	70.46		52.58		98.28	
			80.17	N=11	91.43	
		N=13			86.94	
					67.78	
				41.79		
				70.14	N=11	

PARAMETER	EXPERT REGULATION		NOVICE REGULATION		NOVICE EXPERIMENTAL	
Angle of Elbow at Release	133.18 ^o	141.20	136.30	129.88	150.3	103.8
	152.78	124.17	164.00	152.50	112.7	101.8
	152.53	134.28	154.74		-	120.5
	162.23	141.32	127.50		-	
	146.51		96.42		-	
	116.38		133.50		-	
	150.78	N=14			-	
	151.67			N=8	126.0	
	138.91					
	132.30					N=6
Angle of U.L. at Release	53.00 ^o	59.67	50.75 ^o	64.00	36.75	
	58.58	49.75	59.38	40.00	34.63	
	53.75	48.75	57.75		45.25	
	58.33	55.38	41.00		58.00	
	58.50	41.00	44.38		57.50	
	55.75	42.50	61.00		41.00	
	62.13	52.17		N=8		N=6
		N=14				

PARAMETER	EXPERT REGULATION		NOVICE REGULATION		NOVICE EXPERIMENTAL	
Wrist Velocity at Release	8.66m/s	6.77	6.22m/s	3.75	3.29	7.80
	8.30	10.26	5.94	4.88	4.97	6.26
	5.67	7.74	4.07	4.94	-	4.05
	8.72	7.21	3.75	4.00	4.83	-
	7.25	6.77	4.88	2.31	6.41	-
	9.92	9.33	4.18		5.04	6.80
	8.08	9.28			4.75	
				N=11	7.65	
	N=14				N=11	
Ball Velocity at Release	12.89m/s	9.99	8.70m/s	7.87	6.13	-
	13.92	13.45	8.75	6.63	-	8.69
	10.43	14.91	6.87	5.35	6.56	8.10
	13.19	13.27	6.24	6.01	-	-
	11.41	11.91	7.19		-	-
	11.06	11.91	6.87		-	-
		14.60			7.53	
					8.44	
	N=13		N=10			
Location of Ball During P1	71.43% - No contact during P1		86.3% no contact during P1		93.75% no contact during P1	
	28.57% - chin, forearms etc.		13.7% contact		6.25% contact	
	N=28		N=22 (trials)		N=16	

APPENDIX G

Matched Subject Data

Matched Group Data

Mean

Parameter	NE	NR	df	t-ratio
Age (years)	10.8	10.0	22	-2.58
Swim Speed (m/s)	14.2	14.5	16	0.42
Height (cm)	146.2	139.1	20	-2.45
Weight (Kg)	38.2	32.3	21	-1.69
Hand Span (cm)	18.2	17.9	23	-.69

$p < .01$

APPENDIX H

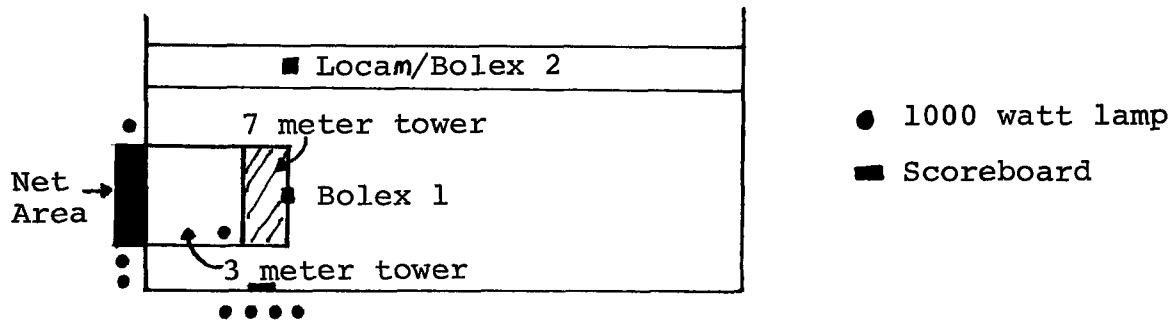
Film Records

FILM RECORD

82

PURPOSE Masters Thesis, KLN 7999 DATE 22/07/77 & 18/12/77
INVESTIGATOR Denise Pittuck LOCATION Ottawa University
TIME STARTED 12:00 noon/8:00 am TIME ENDED 3:30 pm/11:30 am
CAMERA Locam/Bolex 2 FRAME RATE 64 fps SHUTTER 2.8, p-2
EXPOSURE TIME _____ LENS 42 mm f/STOP 2.8
LIGHT CONDITIONS indoor pool lights
ARTIFICIAL LIGHTS (number & type) 8- IANEBEAM lamps, 1000 w/each
BACKGROUND indoor pool wall
REFERENCE MARKERS 1-meter pole, L-bar in horizontal field
IDENTIFICATION Scoreboard - Subject/Trial
CAMERA SPEED CALIBRATION Photo cell housed in camera, 100 hertz
CAMERA HEIGHT Set on Bulkhead of pool CAMERA-SUBJECT DIST. 19.8m

DIAGRAM OF FILMING SITE



SUBJECTS (number, joint markings, etc.) Both shoulders, elbow and wrist of shooting arm was marked with white adhesive tape and black dots.

FILMING SEQUENCE (scale, trial, order, etc.) Scoreboard identified subject and trial order. Order was also recorded by investigator

COMMENTS Poor lighting conditions limited the investigator to using a lower frame rate than was desired

FILM RECORD

83

PURPOSE Masters Thesis, K1N 7999 DATE 22/07/77 & 18/12/77
INVESTIGATOR Denise Pittuck LOCATION Ottawa University
TIME STARTED 12:00 noon/8:00 am TIME ENDED 3:30 pm/11:30 am
CAMERA Bolex 1 (overhead) FRAME RATE 48fps SHUTTER 2.8
EXPOSURE TIME _____ LENS 17mm f/STOP 2.8 p-1
LIGHT CONDITIONS indoor pool lights
ARTIFICIAL LIGHTS (number & type) 8 - IANEBEAM lamps, 1000w/ea
BACKGROUND indoor pool wall
REFERENCE MARKERS 1-meter pole, recorded on deck
IDENTIFICATION Recorded by investigator on deck
CAMERA SPEED CALIBRATION stopwatch
CAMERA HEIGHT none CAMERA-SUBJECT DISTANCE 7 meters
DIAGRAM OF FILMING SITE

Same

SUBJECTS (number, joint markings, etc.) Both shoulders, elbow and wrist of shooting arm was marked with white adhesive tape and black dots

FILMING SEQUENCE (scale, trial, order, etc.) Recorded on deck by the investigator as the filming took place.

COMMENTS There was no problem with lighting conditions since the overhead camera field benefitted from the underwater pool lamps and the water reflection.

Timing and Multipliers

TIMING

Novice Regulation

	<u>Set Frame Rate</u>	<u>Actual Frame Rate</u>	<u>Time/frame</u>
Locam	64 fps	61 fps	.016s
Bolex	48 fps	48 fps	.021s

Novice Experimental

Bolex 1	64 fps	64 fps	.016s
Bolex 2	48 fps	48 fps	.021s

MULTIPLIERS

Novice Regulation

	<u>X</u>	<u>Actual</u>	<u>Multiplier</u>
Locam	.049m	1m	20.41
Bolex	.054m	1m	18.52

Novice Experimental

Bolex	.068	1.75m	25.74
Bolex	.067	1.75m	26.12
Bolex	.076	1.75m	23.03