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## Head motion in overarm throwing for children with varying levels of motor proficiency

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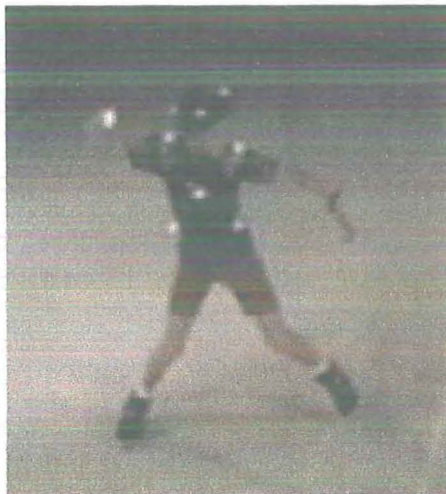
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**HEAD MOTION IN OVERARM THROWING FOR  
CHILDREN WITH VARYING LEVELS OF MOTOR  
PROFICIENCY**

By

Kevin J. Netto



A thesis submitted in partial fulfilment of the requirements for the award of  
Bachelor of Science (Sports Science) Honours'

At the Faculty of Science and Technology,  
Edith Cowan University, Joondalup Campus.

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## USE OF THESIS

The Use of Thesis statement is not included in this version of the thesis.

## ABSTRACT

The overarm throw has been classified as a fundamental motor skill that is the basis for a number of more complex sporting skills. There are a number of developmental stages over which a child progresses to the mature form of the skill. Control of the overarm throw, especially towards a target is very dependent on visual and vestibular information for successful execution. The quality of the information is, in turn, dependant on the head movement of the performer during the execution of the skill. It has been reported that head angular velocities above 350 degrees/second result in a degradation of useful visual and vestibular information and as such, a loss in control of the performed skill. The purpose of this study was to investigate head movement in children while they performed an overarm throw towards a forward facing target. The study also investigated the possible relationship between motor proficiency of the thrower and their head movement. Three hypotheses were investigated. These included:

1. The head is stabilised during the throw.
2. The head is stabilised throughout the performance until close to ball release where it will move with the trunk as part of the 'kinetic chain'.
3. Subjects with lower levels of motor proficiency stabilise their head less over the whole performance when they are compared to subjects with higher motor proficiency levels.

Ten, ten-year-old children of mixed gender and varying levels of motor proficiency participated in the study. Subjects were video recorded performing an overarm throw towards a forward facing target. Their throwing proficiency was assessed using a standard motor test. The video of the throw was digitised and analysed to produce angular velocities profiles of the head and trunk about different reference axes.

It was found that all of the subjects except one stabilised their head throughout the whole throwing performance. It was also found that the subjects

stabilised their head intentionally and independently despite large trunk angular velocities near the end of the performance. These findings support hypotheses 1 and 2. No significant relationship was found between motor proficiency and head movement. Thus hypothesis 3 remained unsupported.

Further research with a larger sample size and changes to the motor proficiency-testing regime are required to investigate the possible relationship between motor proficiency and head movement.

## DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any institution of higher education; and that to the best of my knowledge and belief it does not contain any material previously written by another person except where due reference is made in the text.

Signature\_

Date 22-3-00

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## CHAPTER ONE

### INTRODUCTION

Gross fundamental motor skills are typified as a group of basic movement patterns that require the use of large muscle groups in execution. These skills are the cornerstone of more complex, sport specific skills (Sprinkle, Larkin & Vine, 1997, p2). Included in this group are the skills of walking, running, catching, striking and throwing.

Children normally develop gross fundamental motor skills from the ages of two through to about twelve years (Wickstrom, 1977, p 94). A number of tests have been devised to assess children and their developmental proficiency at these skills. One of these is the 'Test for Gross Motor Development' (TGMD). This test examines a number of essential observable characteristics of gross motor skills and scores the performer against the mature form of the skill (Ulrich, 1985). Thus a numerical score of motor proficiency can be obtained for the performance.

The skill of overarm throwing is a gross fundamental motor skill that has its origins when children first start to squash, shake, drop and throw objects. It is a movement that involves pushing an object away from the body or passing it to another person (Marques-Bruna & Grimshaw, 1997, p. 1267). In biomechanical terms, the overarm throw has been characterised as a multi-segmented skill, which relies on the generation of torque around joints to produce linear motion of a projectile (Kreighbaum & Barthels, 1996, pp. 370-371).

Many sports skills are an advanced version of the overarm throw. These include the baseball pitch, throwing in cricket, javelin throw, tennis serve and basketball pass (Walkley, Holland, Treloar & Probyn-Smith, 1993, p. 11). Thus, understanding the criteria that affect the performance and control of an overarm throw will also provide insight into the factors that affect the performance and control of these more complicated sporting skills.

The importance of the head in the control of fundamental motor skills is basically twofold. The head can be seen as a link in the kinetic chain of the particular movement. Since the head is an extremity of the body with substantial mass, it might be hypothesised that the head would move in some 'kinetic chain' fashion during the performance of an overarm throw. This would be mainly due to the torques generated to produce the throw around the other joints of the body. When, and for how long this happens is unknown.

The head can also be categorised as a source of sensory information as it contains "the two most important perceptual systems for detecting self-motion with respect to space", namely, the visual and vestibular (Pozzo, Berthoz & Lefort, 1990, p. 97). These two systems provide feedback during the execution of a performance and feedback after execution to allow modification of a particular 'motor program'. These systems also help maintain balance during the whole performance of the movement.

Overarm throwing performance is greatly affected by perceptual skills,

motor skills and inter-segmental mechanics (Marques-Bruna & Grimshaw, 1997, p. 1267). Studies have explored the importance of visual perception and the performance of throwing. Most results suggest continuous visual information during the performance of the skill to be paramount to success of the performance (Elliot & Leonard, 1986, pp. 518-519). In other words, some form of visual control must exist for successful performance of the skill.

Head stabilisation in space during natural human movements is imperative for maintaining visual stability (Keshner & Chen, 1996, p324). Interruptions in sensory input can be caused by less-than-perfect stabilisation. To allow for optimum visual sensory input, the head must therefore be controlled or stabilised in some fashion (Pozzo et al., 1990).

Pulaski, Zee and Robinson (1981) reported a marked deterioration in the quality of visual information as head angular velocity increased during acrobatic movements. It was also indicated that for head angular velocities above 350 degrees/second, visual information became impossible to use. In a study of backward somersaults, Pozzo, Berthoz and Lefort (1989) concluded that for tasks involving visual targeting, the position of the target would determine the point of gaze. When placed in the context of this study, these statements would lead to an assumption that there would be a period of head stabilisation during the throw to allow for visual targeting. This would imply that the resultant head angular velocities with respect to an external reference frame would be below 350 degrees/s for some period of time during the execution of the throw. When this stabilisation would cease, however, is unknown.



From the rationale of visuomotor control stated in the last few paragraphs, a model was developed to diagrammatically represent a number of control mechanisms in the fundamental motor skill of overarm throwing. This model was based on Jeannerod's (1986) proposed model of visuomotor control, which was developed using a number of normal and brain damaged subjects. The study hypothesised the importance of two main sensory receptors, vision and proprioception as control mechanisms to 'motor programs'.

The developed model (see Fig. 1) shows the interaction between vision and proprioception, and feedback and 'motor programs' in the control of an overarm throw. It outlines the importance of head movement for the accessibility of visual information. It displays the role of head stabilisation and also develops a rationale for the variables that were used to measure head movement and stabilisation in this study.

From the model and the above-mentioned literature, the importance of vision and head stabilisation in the control of an overarm throw is clearly understood. A question that arises is whether there is a lessening of reliance on vision for control when the performer of the throw becomes more proficient at the skill. Robertson, Collins, Elliott and Starkes (1994) reported a lessening of reliance on vision by expert performers as compared to novices in a beam walking balance exercise.

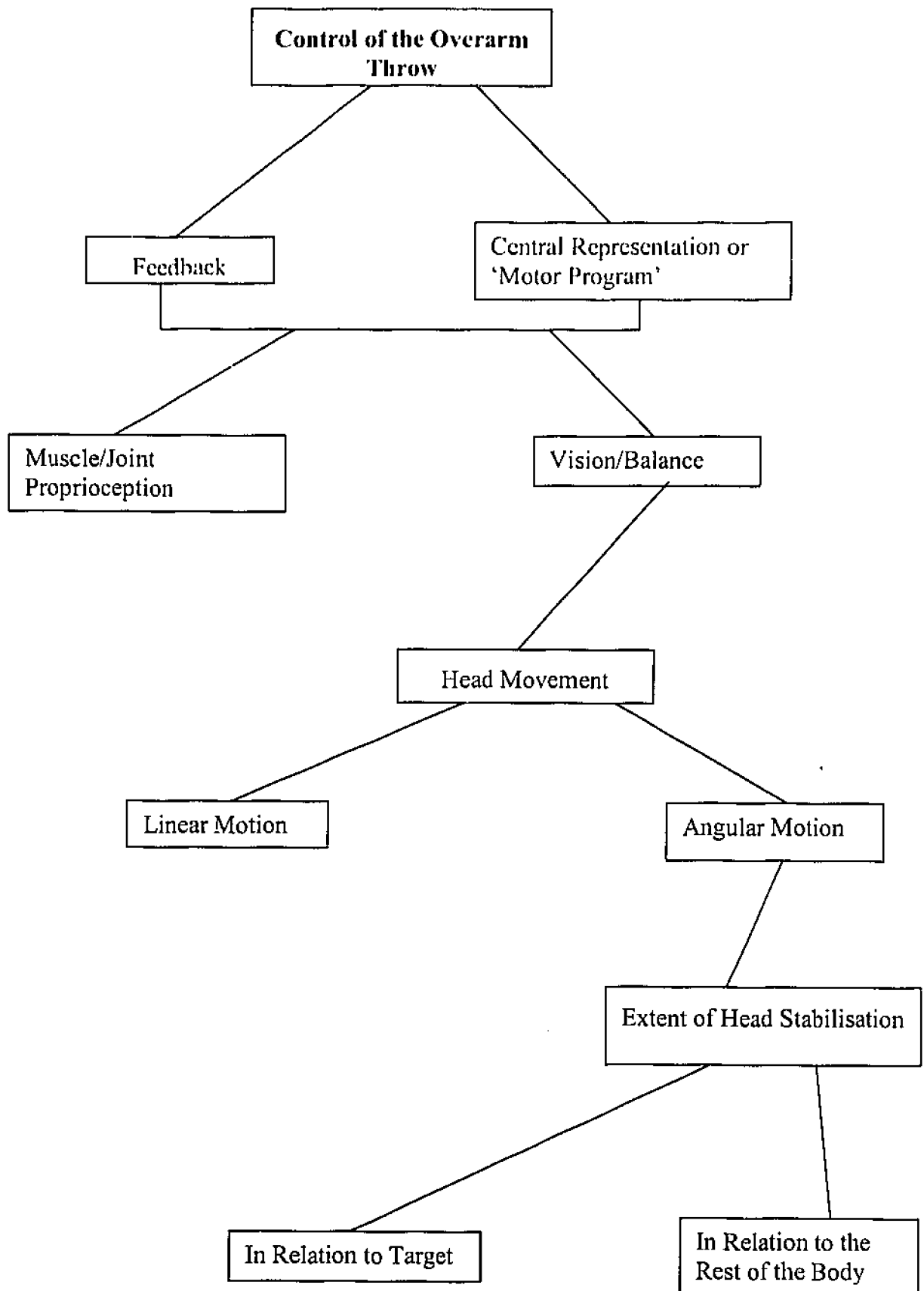


Figure 1. Conceptual model of control in an overarm throw (Jeannrod, 1986)

They hypothesised that the experts formed some sort of central representation or 'motor program' for the task. However, in a qualitative study of children with impaired motor proficiencies, Larkin and Hoare (1991, p. 103) reported that children with lower motor proficiencies tended not to focus on the target when performing an overarm throw. Also, since the overarm throw is a dynamic activity, movement by certain segments of the body must influence other segments. Vereijken, van Emmerik, Whiting and Newell (1992) reported a 'release of degrees of freedom' in joint angles, as a performer became more proficient at a skill. This would suggest some variance in head and trunk movements for different subjects in this study.

From these studies, it is quite unclear how motor proficiency interacts with head movement and stabilisation. Would more motor proficient subjects stabilise their head more or less than less proficient subjects? Does the head move independently of the rest of the body during the throw? Would more motor proficient subjects have more segmental independence than less motor proficient subjects? Or would they move their head with the rest of the body in some form of 'kinetic chain'? All these questions have been left unanswered by the studies.

To date, there has been little or no investigation into head kinematics during the performance of an overarm throw. Therefore, this study investigated head motion in ten-year-old children when they performed an overarm throw towards a forward facing target. It focused on the angular velocity profiles of the head with respect to an external reference frame to investigate how the head might be stabilised in relation to the target to allow for visual information and feedback. It also measured these variables with respect to an internal frame of reference (the trunk) to assess whether the head was deliberately controlled independently of

other body parts to optimise the quality of vestibular ocular information. A motor proficiency score for each subject was also measured to assess whether head motion was related to throwing ability.

### Research Questions

In light of the fact that vision is paramount for control in an overarm throw, and that head stabilisation facilitates this sensory input, the following questions were addressed.

1. Is there evidence that the head is stabilised to perform an overarm throw to a target?

To perform an overarm throw, torques must be generated about joints. These torques must influence the head's movement in some fashion during the throw. Thus, it seemed important to ask:

2. When, and for how long does stabilisation occur?

From the introduction it was noted that some studies have reported less stabilisation in more skilled performers, and others have reported a lack of stabilisation in less skilled ones, it was seen as important to investigate the extent to which head movement related to motor proficiency in this study.

3. Is there a relationship between the extent and timing of head stabilisation and

motor proficiency in this study?

### Hypotheses

Firstly, it has been reported that vision is paramount for control in targeting activities, and that some form of head stabilisation is needed to facilitate quality visual information. Secondly, the skill of overarm throw is dynamic by nature, and as such produces large torque about joints. Thus, it would seem pertinent to assume:

1. The head is stabilised during the throw.
2. The head is stabilised throughout the performance until close to ball release where it will move with the trunk as part of the 'kinetic chain'.
3. Subjects with lower levels of motor proficiency stabilise their head less over the whole performance when they are compared to subjects with higher motor proficiencies.

### Limitations

This study was delimited to ten-year-old Perth school children of mixed gender. Accommodating a larger, more varied sample group was not within the scope of this study due to time limitations of an honours' study.

## Definition of Terms

Table 1 outlines a list of terms used in this study and operationally defines them.

Table 1

### List of Terms Used in the Study

<b>Term</b>	<b>Definition</b>
The start of the throw	Identified as the point in time at the beginning of the performance where there is a ten-centimetre difference in y -axis displacement between the right and left shoulder markers.
The end of the throw	Identified as the point in time when the ball attains a horizontal velocity of 0.2 m/s with respect to the throwing hand.
The whole performance	The period of interest demarcated by the start of the throw and the end of the throw.
Somersault	Motion of the head or trunk about its medio-lateral axis.
Tilt	Motion of the head or trunk about its anterior-posterior axis.
Twist	Motion of the head or trunk about its longitudinal axis.
Head Stabilisation	Resultant and component head angular velocity below 350 degrees/s.
Motor Proficiency	Percentile test score from the TGMD test regime.

## CHAPTER TWO

### REVIEW OF LITERATURE

To date, there have been few studies published on the subject of head kinematics in overarm throwing. However, a number of related research studies have been conducted. In the area of head kinematics, there have been a number of studies that have focused on head movement and stabilisation during the performance of acrobatics, locomotion and balancing activities (Pozzo et al., 1989; 1990; Sanders, 1994; Robertson et al., 1994; Keshner & Chen, 1996). Also, a number of other studies have alluded to the role and importance of vision for control of movement skills (Elliott & Leonard, 1986). In terms of overarm throwing, Larkin and Hoare, (1991) identified the need for some form of stabilisation during the throw.

This review of literature focuses on a number of areas. First, ideas related to overarm throw and proficiency levels are discussed. Then, the role of vision in the control of motor skills is addressed. Finally, the idea that head stabilisation is a contributing factor to throwing performance is discussed.

## The Overarm Throw

The overarm throw has been characterised as an open kinetic chain movement in a closed environment (Kreighbaum & Barthels, 1996, p. 302). The skill relies on torque generated about joints to produce linear motion of the projectile (Kreighbaum & Barthels, 1996, pp. 370-371). The overarm throw has a direct use in many sports. These include baseball, softball and cricket. Even the service actions in tennis and squash have a movement pattern that has its origins in the overarm throw (Anderson & Elliott, 1991).

Wilde (1938), proposed four stages through which children develop the skill of overarm throwing (Kreighbaum & Barthels, 1996, pp. 382-383). These four stages are displayed in Table 2. The critical features of each stage made up the checklist for the motor proficiency test used by Ulrich (1985). This checklist was also adapted for use in this study (Appendix A).



Table 2

Stages of Development for the Skill of Overarm Throwing

Stage	Characteristics
1	Elbow located forward of the shoulder joint. Ball thrown primarily with elbow extension No rotation of the thorax is visible
2	Thorax rotation accompanies backward motion of arm Throw initiated by arm swing forward with follow through of thorax rotation to non-dominant side Elbow extends at variable times during forward swing
3	A step is taken with the dominant side foot (ipsilateral) Step followed by thorax rotation and forward arm swing Elbow extension occurs later than stage 2
4	Step taken with non-dominant side foot (contralateral) Thorax rotation with follow through Transverse abduction of the shoulder Near full elbow extension at ball release

(Kreighbaum & Barthels, 1996, p. 383)

From this table, it can be noted that as the performer develops the skill, there is an increased utilisation of different segments of the body. This supports Vereijken et al. (1992) who studied the changes in joint angles, as novices became more skilled at a specific task. They reported a 'freezing of degrees of freedom' during the early stages of skill acquisition and a significant increase in joint angles

as the skill was learnt. This leads to the possibility that subjects with higher motor proficiency scores in this study would have greater angular velocities of the head with respect to the trunk.

A number of motor control theories have been raised in relation to targeting and throwing accuracy (Marques-Bruna & Grimshaw, 1997, p. 1267), most of which lie outside the scope of this study. However, there has been some attention given to the role of vision in the control of throwing. In a study of visual guidance in throwing in adults, Davis (1984, pp. 759-768) investigated the use of a visual guide (a small red dot on the target) in throwing accuracy. The study found no improvement in throwing accuracy when the subjects were instructed to focus on the dot throughout the throw.

In a study of visual delay on throwing performance, Elliott and Leonard (1986, pp. 518-519) examined the effect of a total vision condition and no-vision delay condition on throwing accuracy. They found evidence to show that there is no substitute for continuous vision during the performance of a throw.

### The Role of Vision

Vision has been identified as the chief source of information for the control of movement from outside the body (Schmidt, 1991, p 46). Vision provides information on the position of objects in space, such as targets and flight paths of balls.

In a study of balance beam walking by novices and experts, Robertson et al. (1994) suggested that visual feedback was less important for expert subjects as there was evidence that these subjects developed a central representation or programme for the task over repeated practice sessions. This would suggest that subjects with higher levels of motor proficiency would rely less on visual feedback and thereby stabilise their head less than skilled subjects.

O'Brien, Cermak and Murray (1988, pp. 357-359) examined the relationship between visual-perceptual motor abilities and clumsiness in children with and without learning disabilities. They reported a significant correlation between visual-perceptual motor ability and degree of clumsiness of the subject. They also concluded that more research was needed into areas of visual-spatial analysis and/or analysis of activities integrating visual and motor components of the performance. These findings suggest that subjects in this study with low motor proficiency scores would exhibit less head stabilisation when compared to subjects with higher scores.

### Head Stabilisation

The process of sensory input during human movement can be affected by less-than-perfect head stabilisation (Keshner & Chen, 1996, p. 324). Head stabilisation is essential for maintaining visual stability in human movement. In biomechanical terms, head stabilisation is a measure of angular velocity of the head with respect to an external reference frame. Pulaski et al. (1981) estimated an upper limit of 350 degrees/second as a threshold for the use of visual information.

A number of head stabilisation studies have dealt with the topic in reference to sporting movements, such as diving and acrobatics, and in the area of locomotion (Pozzo et al., 1989; 1990; Sanders, 1994). Pozzo et al. (1990) found that head stabilisation occurred intermittently during a backward somersault. The two main periods of stabilisation occurred during the take-off and just before landing. It was also reported that the direction of stabilisation was directed towards the landing surface. They concluded that for tasks involving some form of visual target, the direction of stabilisation would be in the direction of the target. This would indicate that, in the performance of an overarm throw towards a target, the head of the performer would be stabilised in the direction of the target. When, and for how long the head would be stabilised in that particular direction is unknown.

In terms of motor ability in children, only qualitative data have been reported (Larkin & Hoare, 1991, p. 103). It was found that when performing an overarm throw, children with impaired motor ability tended to have poor head control and their eyes did not focus on the target. This suggests that less motor proficient subjects would exhibit less head stabilisation with respect to the target. As such, angular velocity profiles with respect to the external reference frame would be higher in these subjects.

## Summary

Visual dominance in the control of fundamental motor skills, such as overarm throwing has been established. To allow for any sort of useful visual information, the head of the performer must be stabilised below 350 degrees/second for some period during the execution of the skill. It has been hypothesised that as a performer becomes more skilled, there is an increase in the amount of freedom about joints in the body. Also, it has been reported that during the performance of an overarm throw, the head could move as a result of torques generated about joints. This would suggest the performer of an overarm throw would have to deliberately control their head in some fashion. When, and for how long this happens during the performance of an overarm throw is still unclear.

Qualitatively, it has been reported that children with impaired motor proficiency did not focus towards the target during the performance of overarm throwing. This would suggest that a relationship between head motion and motor proficiency exists. However, it is unclear whether subjects with higher motor proficiencies stabilise their heads more when compared to less motor proficient ones or vice-versa.

Therefore, this study endeavoured to quantify the extent of head stabilisation during an overarm throw. It also investigated the relationship between motor proficiency and head motion during the performance of overarm throwing in ten-year old children with varying levels of motor proficiencies.

## CHAPTER THREE

### METHOD OF INVESTIGATION

#### Sample

In total, ten subjects of mixed gender (2 male, 8 female) were tested. The subjects were all ten years of age and were sourced from local primary schools. All subjects with any form of physical or medical disorder, which was likely to impair their ability to perform a throw, were not accepted for the study. All participants in the study and their parents/guardians received a one-page summary outlining the study, its purpose and procedure. Parents/guardians of subjects completed and signed a consent form. A copy of the one-page summary sheet is given in Appendix B. A copy of the consent form is given in Appendix C.

#### Motor Proficiency

Motor proficiencies of all subjects were evaluated using the Test for Gross Motor Development (TGMD) protocol (Ulrich, 1985). The checklist used is given in Appendix A. A motor control consultant with experience in motor development evaluation helped with grading the subjects. The subjects were graded using the captured video of each trial. All scores were converted to a percentage value for easy comparison.

## Equipment Used

Table 3 lists the equipment used in this study.

Table 3

### List of Equipment Used in the Study

<b>No of</b>	<b>Equipment</b>
6	8 mm variable shutter speed video cameras
6	Multidirectional tripod heads
10	8 mm blank video tapes
6	100 watt halogen spot lights
10	Electrical extension cords
1	Pentium 2, 450 MHz IBM compatible personal computer
1	Matrox video capture interface and software
1	Ariel Performance Analysis System (APAS) software
1	AVI2BLD frame rebuilding software
1	8 pointed calibration cube
1	Cloth skull cap
15	12 mm reflective balls
2	Micropore tape
1	Moveable screen (green background)
1	A3 size target (420 x 297 mm) (white)
1	Tennis ball (yellow)

## Data Collection

Data collection was carried out over a three-week period in the performance laboratory of Edith Cowan University. The data were collected using six Video 8 cameras placed circularly around the subject. The cameras captured data at 50 fields/second. Reflective markers (12mm balls) were secured to eight landmarks on the subject. An additional reflective dot was pasted on the centre of the ball. A list of these markings is given in Table 4.

Table 4

### List of Markings that were Captured

<b>Name</b>	<b>Landmark</b>
Right FP	Right side of the skull-cap, in a translated line with the right "Frankfort plane" marking
Left FP	Left side of the skull-cap, in a translated line with the left "Frankfort plane" marking
Mid FP	Rear of the skull-cap bisecting the left and right FP points
Right Shoulder	Lateral aspect of the right acromium process
Left Shoulder	Lateral aspect of the left acromium process
Right Hip	Right lateral aspect of the iliac crest
Left Hip	Left lateral aspect of the iliac crest
Right Hand	Third knuckle on the posterior face of the right hand
Ball	Centre of the ball



In a number of studies, the 'Frankfort Plane' has been used to characterise both the visual and vestibular system. This plane is normally defined by a line between the lower border of the eye-socket and the meatus of the ear. These markings are usually translated to a posterior marking on the neck or head. These three markings give a kinematic representation of the head in space. (Pozzo, et al., 1990, p. 98)

In this study, a head axis system was defined using a plane approximately parallel to the 'Frankfort Plane' using markers attached to a skull cap. From pilot work, it was found that attaching markers to the subject's face which define the 'Frankfort Plane' was uncomfortable for the subject and interfered with the performance of the throw. Therefore, from secondary pilot studies, it was found that securing markers to the tight fitting skullcap gave an accurate translation of the 'Frankfort Plane' (Fig. 2). As such the skull cap was used.

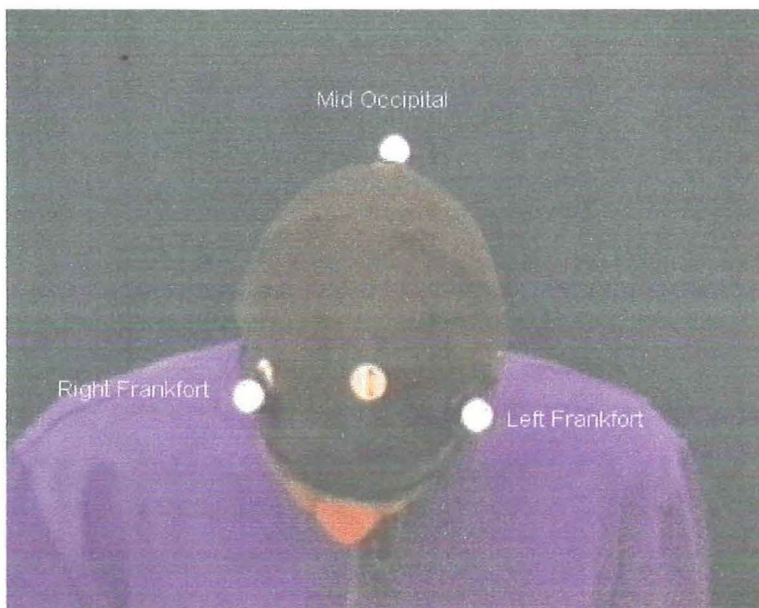


Figure 2. Top view of skull cap with 'Frankfort Plane' markers

Each subject performed a ten-throw warm-up with a partner. The ball used was a standard tennis ball. This warm-up was followed by a stretch of the shoulder girdle muscles. The subject was then instructed to perform three solo throws towards a forward facing wall. The verbal instructions given were to "Throw the ball as hard as you can towards the wall". These throws acted as a familiarisation to the trials. A movable screen with a standard A3 (420 mm x 297 mm) target was then placed in front of the subject. The target was white and contrasted well with the dark green background of the screen. The target was secured to the screen at the subject's eye level and placed four metres in front of the subject. The subject was then instructed to perform an overarm throw of the tennis ball towards the forward facing screen. The verbal instructions given were to "Throw the ball as hard as the previous throws but try to hit the target". Each subject performed three trials. Five extra trials were performed by the last subject for assessing inter-trial variability.

#### Selection of Variables for Analysis

The variables selected for analysis were based on the research questions asked. For Research Question 1 (RQ1), "Is there evidence that the head is stabilised to perform an overarm throw to a target?", the variables selected were:

1. Maximum component and resultant head angular velocity with respect to the external reference frame.

The resultant velocities gave an overall picture of the movement of the

head. The component velocities gave a more in depth analysis of stabilisation or non-stabilisation in particular directions. The 350 degrees/s threshold was adopted as an upper limit of head stabilisation. The external reference frame was used as a reference to investigate the head's movement independently.

2. Maximum component and resultant angular velocity of the head with respect to the trunk reference frame.

These variables gave a clearer picture into how the head was stabilised with respect to the rest of the body.

3. Comparison between the mean resultant head angular velocity profile with respect to the external axis, and the mean trunk angular velocity profile with respect to the external axis across all the subjects.

This showed the general trend of all the subjects. It also investigated the independent movement patterns of the head and the trunk.

The list of variables for Research Question 2 (RQ2), "When, and for how long does stabilisation occur?" were:

1. Percentile times when resultant head angular velocity with respect to the external axis was above 350 degrees/s.

This showed periods of non-stabilisation of the head.

2. Percentile times at which the maximum resultant head angular velocity with respect to the external axis occurred.

This showed when the head was stabilised the least.

Research Question 3 (RQ3), “Is there a relationship between the extent and timing of head stabilisation and motor proficiency in this study?” had the following variables:

1. Correlation between maximum component and resultant head angular velocity with respect to the external axis and the score for motor proficiency.

This showed the relationship between motor proficiency and head stabilisation across all the subjects.

2. Correlation between maximum component and resultant head angular velocity with respect to the trunk axis and the score for motor proficiency.

This showed the relationship between motor proficiency and head movement patterns with respect to the rest of the body across all subjects.

## Data Analysis

Each video of the subjects was captured as AVI computer files using a Matrox capture card and software. These AVI files were then 'rebuilt' to 50 frames/second using a commercially available computer program (AVI2BLD).

All views for each trial were automatically digitised using the APAS software. The digitised data were transformed using the direct linear transformation method to produce a three-dimensional co-ordinate data file in ASCII format, which was left unsmoothed, and a three-dimensional positional and velocity data file, which was smoothed at five Hertz using a second order Butterworth digital filter.

## Data Manipulation

The positional and velocity data were transformed from a frame by landmark output orientation to a landmark by frame orientation in Microsoft Access. The data were then transferred to Microsoft Excel where start and end frame were calculated using mathematical models of their definitions.

A customised FORTRAN program (Sanders, 1999) used the co-ordinate data (ASCII) to calculate angular velocity profiles of the head and trunk with respect to the external reference axis, and the head with respect to the trunk axis. It was based on Areblad, Nigg, Ekstrand, Olssen and Ekstrom's (1990) study on foot motion during running. The mathematical manipulations by the program are

listed below.

1. All co-ordinate data read into the Fortran program in text form.
2. Co-ordinate data smoothed at five-hertz using a second order Butterworth digital filter.
3. The internal reference axes were defined using the left and right shoulder markers and the mid-point between the left and right hip markers. (See Fig. 3)

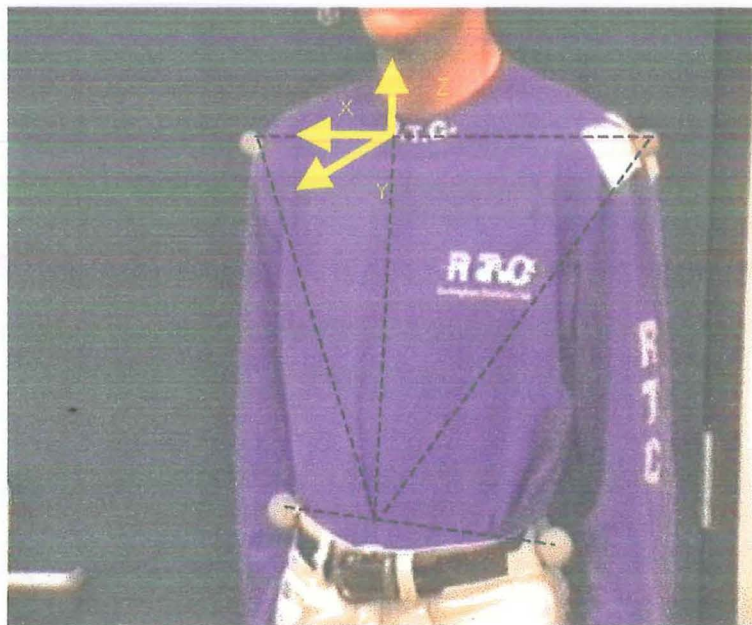


Figure 3. Diagrammatic representation of internal reference axis as defined by trunk markers. Arrows are in the positive direction

4. The change in angle of the head about each head axis, ie. the transverse axis ( $\Delta\alpha$ ), the anterior-posterior axis ( $\Delta\beta$ ), and the longitudinal axis ( $\Delta\theta$ ) were calculated using co-ordinate data of each axis. The same procedure was

applied to calculate the change in angle of the trunk about its axis. The method used for n sample was to use co-ordinates from frame (n-1) and co-ordinates from frame (n+1) in the mathematical formulas:

$$\Delta\alpha_{\text{transverse axis of head or trunk}} = 90^\circ - \arccos (Z_{(n-1)} \cdot (Z_{(n+1)} * X_{(n-1)}))$$

$$\Delta\beta_{\text{anterior-posterior axis of head or trunk}} = 90^\circ - \arccos (Z_{(n+1)} \cdot X_{(n-1)})$$

$$\Delta\theta_{\text{longitudinal axis of head or trunk}} = 90^\circ - \arccos (X_{(n+1)} \cdot (Z_{(n+1)} * X_{(n-1)}))$$

5. The head co-ordinate data were transformed by the trunk reference system. The angular motion of the head with respect to the trunk system was then determined using the same formulas as outlined in 4.
6. These data were then used to calculate angular velocity by multiplying by half the video sampling rate (fs = 50 frames/second). The formulas were:

$$\text{Somersault velocity} = \Delta\alpha * fs / 2$$

$$\text{Tilt velocity} = \Delta\beta * fs / 2$$

$$\text{Twist velocity} = \Delta\theta * fs / 2$$

The positive direction of each component velocity is diagrammatically represented in Fig. 4.

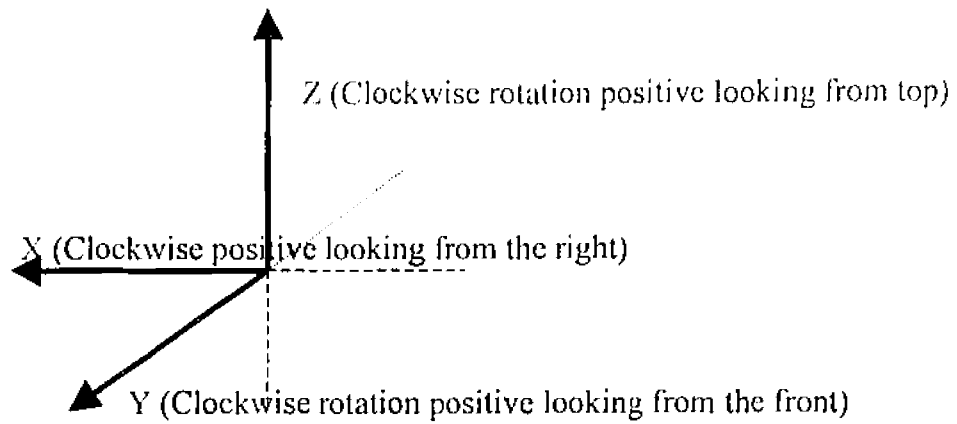


Figure 4. Positive direction for each component velocity

7. All angular velocity profiles were normalised from start and end frames to one hundred percentiles using a quintic spline function.

### Statistical Analysis

To answer RQ1, maximum values were calculated for each subject over all component and resultant angular velocity profiles of the head with respect to the external and trunk reference frames. This was done in Microsoft Excel. Bar graphs were plotted for each subject over the three component velocities.

To answer RQ2, mean head angular velocities were plotted against mean trunk angular velocities across subjects, for the whole performance. The graph was used to ascertain when and for how long the head was stabilised intentionally with respect to the trunk. This test was carried out using the mean resultant head angular velocity with respect to the external axis and the mean resultant trunk



angular velocity with respect to the external axis across all the subjects. A 95% confidence interval envelope of the true mean (one-tail test) graph was plotted to show any significant differences in head and trunk velocities for all the subjects. Significant differences were indicated at time samples where the confidence intervals did not overlap.

To answer RQ3, all the subjects' motor proficiency scores were correlated against maximum resultant and component angular velocities of the head with respect to the external axis and the head with respect to the trunk. A Pearson's correlation was used.

Results

Head and Trunk Angular Velocity Profiles

Maximum Head Angular Velocity

The absolute maximum angular velocities were calculated for each subject across each component i.e. somersault, tilt and twist. No fixed pattern emerged and each subject showed great variability when compared to each other. Only subject ten's tilt component was above the 350 degrees/s threshold. (Fig. 5)

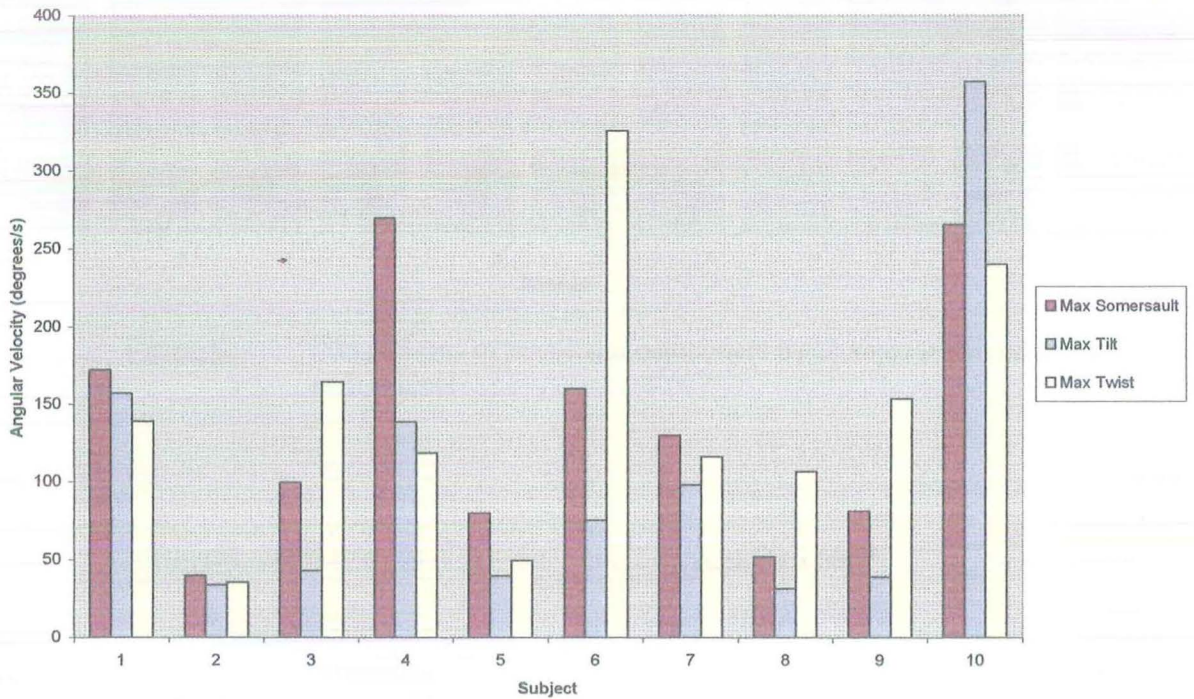


Figure 5. Comparisons of maximum component head angular velocities for each subject

## Maximum Trunk Angular Velocity

Maximum trunk angular velocity values were calculated for each subject. It was found that the twist component was by far the largest component for all the subjects. Fig. 6 gives a comparison for each component for all the subjects.

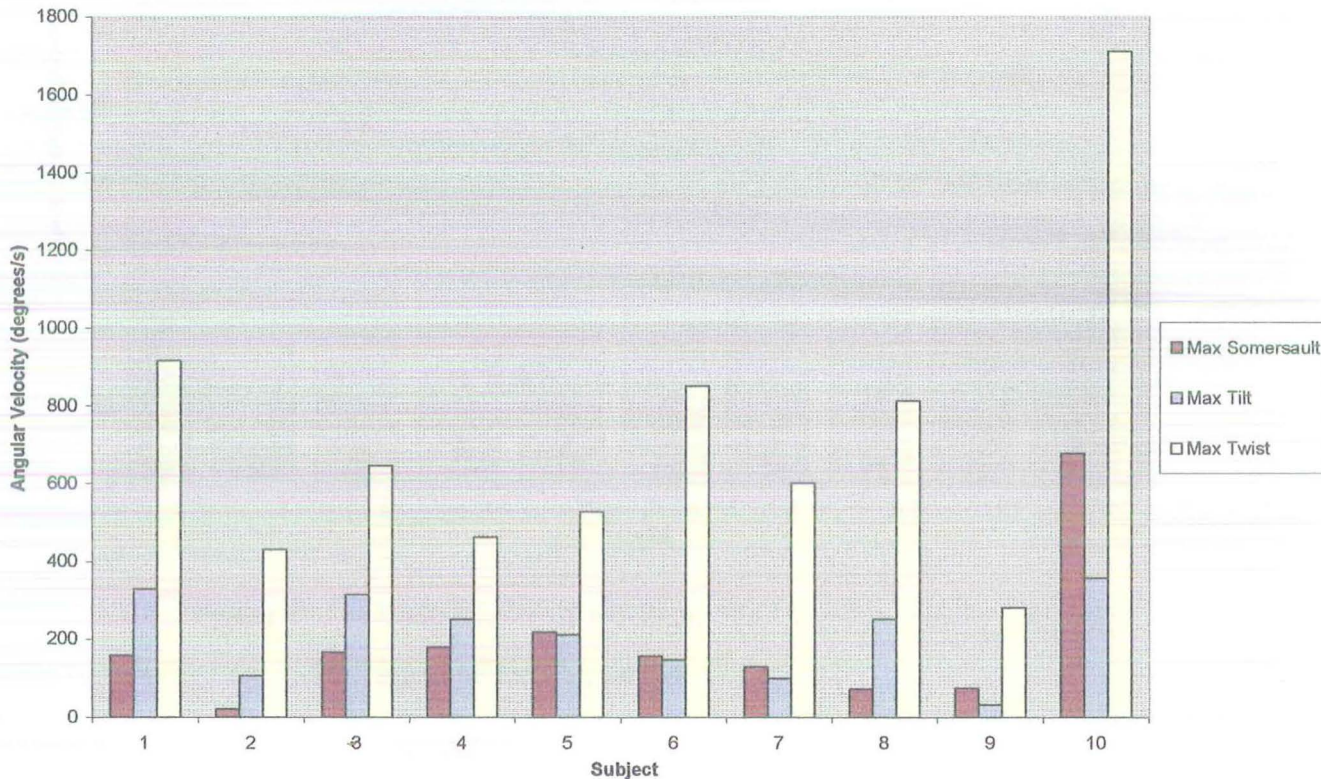


Figure 6. Comparisons of maximum component trunk angular velocities for each subject

## Maximum Head Angular Velocities with respect to the Trunk

Maximum head angular velocities were calculated with respect to the trunk. All the subjects had significantly larger twist components when compared to somersault and tilt. However, this was not true for subjects one and four who



had larger tilt components. Fig. 5 gives a comparison of all three components for each subject.

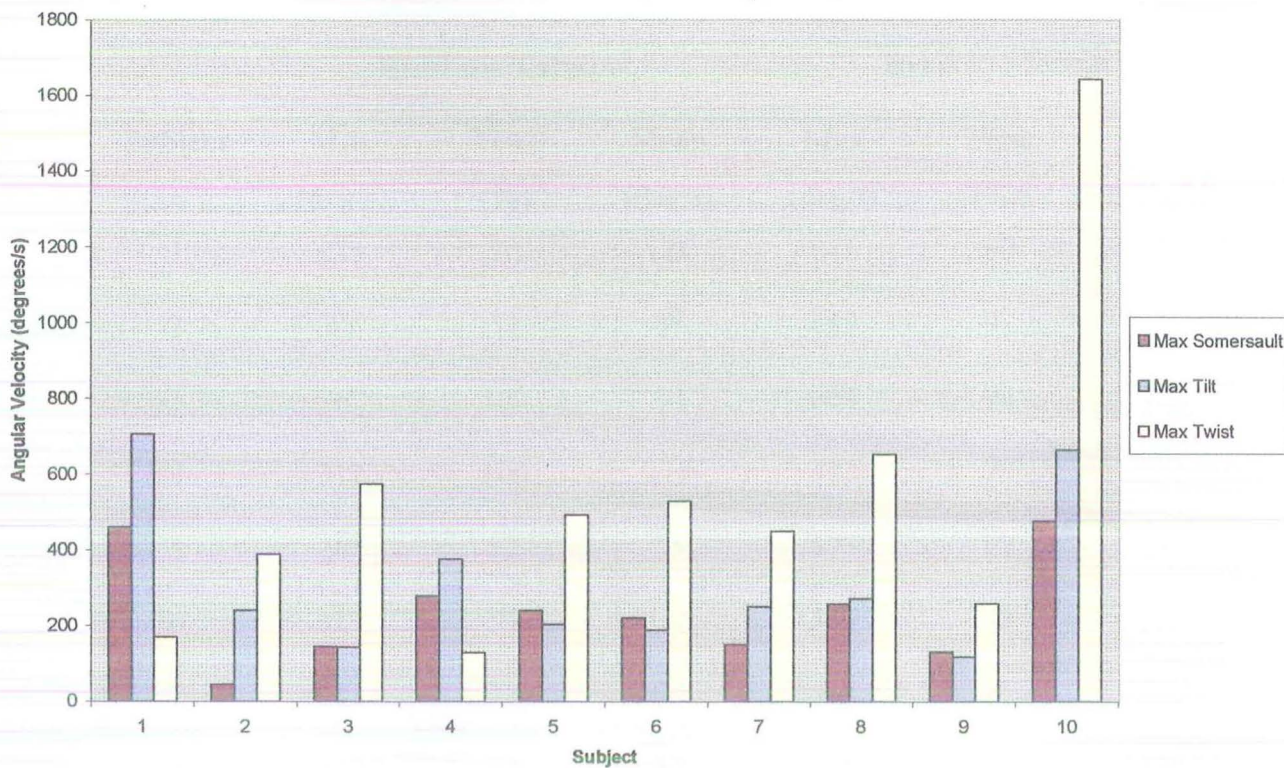


Figure 7. Comparisons of maximum head angular velocity with respect to the trunk for each subject.

#### Maximum Resultant Velocities

Only one subject (subject 10) exhibited a resultant head angular velocity above the 350 degrees/s threshold. (See Table 5) This happened at the 97% and 98% mark of the performance. Most maximums occurred near the end of the performance. Resultant head angular velocities with respect to the trunk axis were a lot larger than resultant velocities with respect to the external axis. This was due to the large trunk velocities at the end of the performance.

Table 5

Maximum and Mean Resultant Velocities and Times at which Maximum Occurs

Subject	Head wrt External			Head wrt Trunk		
	Max (deg/s)	Time (%)	Mean (deg/s)	Max (deg/s)	Time (%)	Mean (deg/s)
1	233	70	121	841	80	199
2	48	52	31	455	91	131
3	167	100	54	604	94	183
4	312	100	118	472	79	131
5	96	92	35	573	97	155
6	329	97	136	573	97	198
7	181	77	80	533	86	203
8	112	94	32	748	94	134
9	156	76	50	291	97	122
10	435	98	134	1768	83	270

## Head Stabilisation

Only one subject exhibited resultant angular velocity above the 350 degree/s threshold. When the one-tail test was performed for mean head angular velocity verses mean trunk angular velocity, both about the external axis, it was noticed that both profiles were within the 95% confidence interval until the 78% mark of the throwing time where a significant difference appeared between the profiles. The graph of these profiles is given in Figure 8.



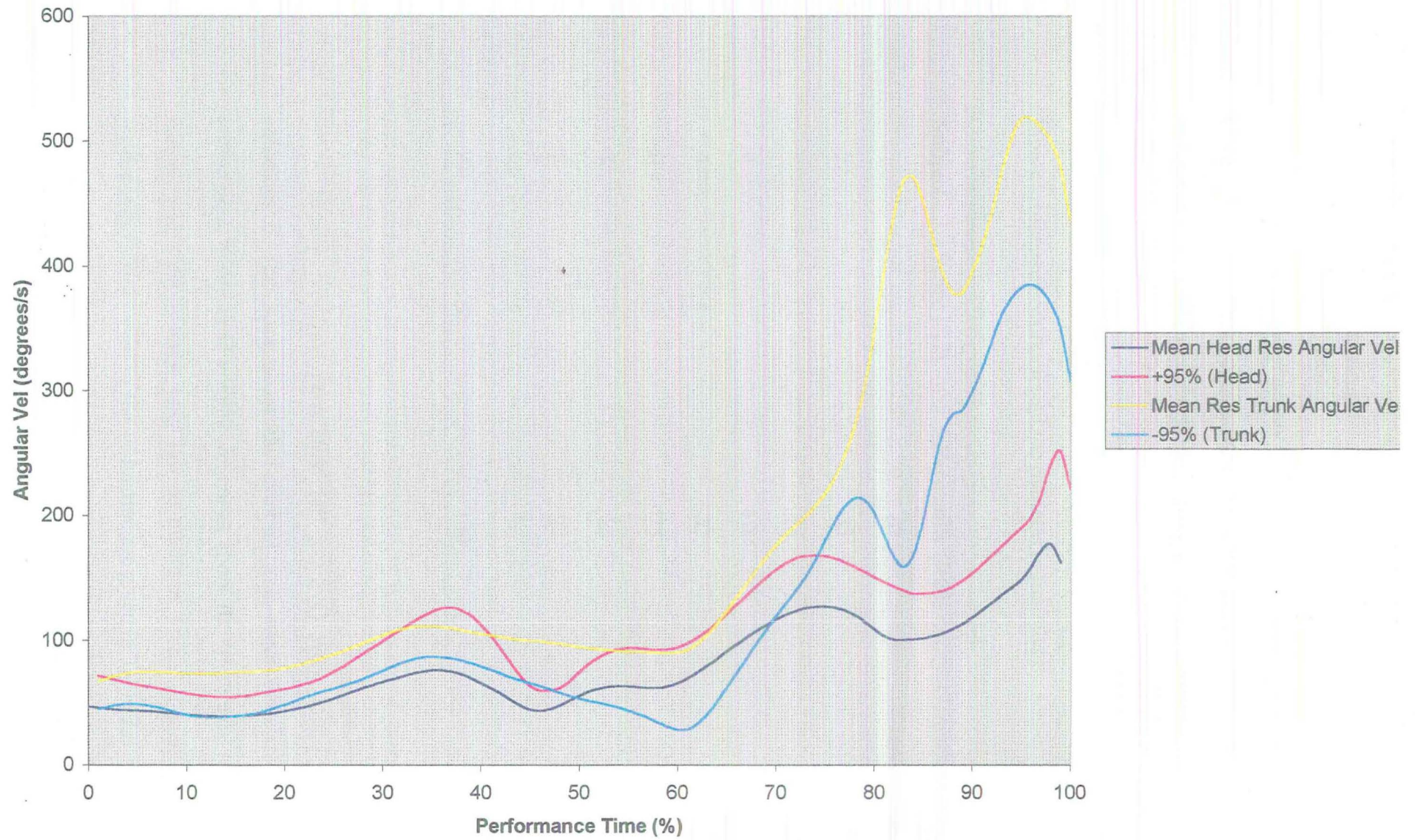


Figure 8. Graphical representation of the true means for head and trunk angular velocities across all subjects

### Motor Proficiency vs Maximum Head Angular Velocity

Motor proficiency scores for each subject were converted to percentile values (Table 6). These scores were then correlated against maximum resultant and component head angular velocities using a Pearson's correlation.

Table 6

#### Motor Proficiency Scores for all the Subjects in the Study

<b>Subject</b>	<b>Score (/12)</b>	<b>Percentile (/100)</b>
1	8	67
2	10	83
3	11	92
4	12	100
5	4	33
6	9	75
7	7	58
8	11	92
9	6	50
10	12	100

Mostly moderate correlation (all positive) were found when angular velocities of the head about the external axis were correlated with motor proficiency. When head angular velocities about the trunk axis were contrasted against motor proficiency, only low to moderate levels of positive correlation were attained. The results of the correlation are given in Table 7.



Table 7

Pearson's Correlation Scores for Each Component

<b>Component Angular Velocity</b>	<b>Co-relation Score</b>
<i>Head with respect to External Axis</i>	
Maximum Somersault	0.44
Maximum Tilt	0.41
Maximum Twist	0.27
Maximum Resultant	0.45
<i>Head with respect to Trunk Axis</i>	
Maximum Somersault	0.22
Maximum Tilt	0.32
Maximum Twist	0.37
Maximum Resultant	0.42

## CHAPTER FIVE

### DISCUSSION

The data analysed and calculated in this study related directly to the research questions asked and the hypotheses made. This discussion section focused on the research questions, which were listed in the introduction and are recaptured below.

1. Is there evidence that the head is stabilised to perform an overarm throw to a target?
2. When, and for how long does this stabilisation occur?
3. Is there a relationship between the extent and timing of head stabilisation and motor proficiency in this study?

A brief overview focusing on one particular subject who had a significantly higher component and resultant angular velocities than any of the other subjects, was included in the discussion on head stabilisation. Finally, a conclusion section outlines all the findings of the study and gives some recommendations for future research into the area of head movement in overarm throwing.

Is there Evidence that the Head is Stabilised to Perform an Overarm Throw to a Target?

From the head angular velocity profiles with respect to the external axis, only one subject (10) crossed the threshold of 350 degrees/s at any time during the performance. This implies that some form of head stabilisation occurred throughout the whole throw for all but one of the subjects. This supports hypothesis one: “The head is stabilised during the throw”.

This stabilisation might have occurred to allow for quality visual and vestibular information for the purpose of correct execution of the skill. These results support the findings of Elliot and Leonard (1986) who stated that vision was paramount in targeting activities.

When, and for How Long does this Stabilisation Occur?

As reported earlier, only Subject 10 had resultant head angular velocities above the 350 degrees/s threshold. This only happened at the end of the performance. It was interesting to note that this particular subject had significantly a larger reading for all measured variables when compared to the other subjects, which indicated large movements about the joints measured. The subject also had the highest motor proficiency score. These findings support those of Vereijken et al. (1992) who hypothesised a release of degrees freedom about joints as a performer becomes more skilled.

From the trend line in Figure 8, mean resultant head angular velocities across all subjects were below the 350 degrees/s threshold for the whole performance. The trend line for the trunk rose to levels above the 350 degrees/s threshold near ball release. There was a significant difference in the trend lines at near 78% of the performance. Given that the head is part of a 'kinetic chain' and that the skill of overarm throwing is a dynamic task, these findings show stabilisation of the head during the throw, especially near the end of the performance where the significant difference between head and trunk velocity existed. These support the findings of Elliot and Leonard (1986) who reported that in throwing, continuous vision was imperative for the control of the performance, and Robertson et al. (1994) who hypothesised the importance of vision in the control of dynamic tasks.

It was interesting to note that most of the subjects' maximum head angular velocities occurred near the end of the performance. This would suggest that the head was starting to move as part of the 'kinetic chain', which supported the second hypothesis, "The head is stabilised throughout the performance until close to ball release where it will move with the trunk as part of the 'kinetic chain'".

#### Is there a Relationship Between the Extent and Timing of Head Stabilisation and Motor Proficiency in this Study?

From the results, it was noted that only moderate levels of positive correlation existed between the motor proficiency of the subjects and maximum head angular velocities. Low levels of positive correlation were exhibited when

these motor proficiency scores were correlated to maximum head angular velocities with respect to the trunk. Thus it was concluded that in this study, no significant relationship existed between motor proficiency and head stabilisation, and hypothesis 3: "Subjects with lower levels of motor proficiency stabilise their head less over the whole performance when they are compared to subjects with higher motor proficiencies" remain unsupported.

These findings differ from those of Larkin and Hoare (1991) who reported a tendency for less motor proficient subjects to not focus on the target during a throw. This could be explained by the fact that the above mentioned study was conducted qualitatively and that the subjects used were all clinically diagnosed with some form of motor disability. The subjects used in this study were normal and only had differences in throwing proficiency.

Another possibility that would account for the lack of any strong correlation is that the motor proficiency test used was not appropriate for the study. The test used compared the mature form of the skill to the subject's form. Therefore, the test inherently suffers from the tester's ability to judge the performance. Performance-based variables such as score of accuracy of the throw or the speed of the ball might have been more appropriate in depicting the subject's proficiency in overarm throwing.

## Conclusion

The results of this study showed that all the subjects except one stabilised their head throughout the whole performance of an overarm throw to a target. The stabilisation of the head was manipulated throughout the throw despite large angular velocities of the trunk near ball release. This implied that the head was being stabilised independently of the trunk and that it was being done to provide optimal quality visual and vestibular information to the performer.

Low to moderate levels of positive correlation were found between resultant and component head angular velocities and motor proficiency. Thus it was inferred that no significant relationship existed between motor proficiency and head stabilisation for this sample. The low levels of correlation could have been due to an inappropriate choice in motor proficiency test regime. Perhaps a more performance-based test would have been more appropriate.

A number of positive steps could be taken in future research into the area of head movement in overarm throwing. First, a larger sample group could be considered. Also, with this group, more varied levels of motor proficiency within the group could also be used. A change in the testing regime for motor proficiency might also show some difference to this study's findings. These changes might have brought about a change in the findings in support of hypothesis 3. Finally, different throwing regimes i.e. throws for accuracy or for speed could also be used as this might show some difference in head movement over the different regimes.

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Developmental Components	Stage 1	Stage 2	Stage 3
<b>Trunk &amp; Head Position</b>			
no trunk rotation, or hyperextension occurs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
trunk rotates to throwing side	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
trunk flexes forward	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Arm Swing</b>			
<i>Preparatory Phase</i>			
ball held in palm	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ball held in fingertips	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
arm swings upward & backward behind head	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
lateral rotation of shoulder occurs	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<i>Action Phase</i>			
arm moves forward with trunk	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
arm lags behind trunk, elbow leads	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
medial rotation of shoulder	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
elbow extension to release ball	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Leg Action</b>			
no weight transfer	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
weight shift onto back foot (preparatory)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
contralateral (opposite foot step)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ipsilateral (same foot step)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>General</b>			
no follow through	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
arm rotates forward on follow through	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
<b>Test for Gross Motor Development (TGMD)</b>		No	Yes

MOTOR PROFICIENCY CHECKLIST I

APPENDIX A

Skill	Materials	Directions	Performance Criteria	Trial 1	Trial 2	Score
Overhand Throw	A tennis ball, a wall, tape, and 20 feet of clear space	Attach a piece of tape on the floor 20 feet from a wall. Have the child stand behind the 20 foot line facing the wall. Tell the child to throw the ball hard at the wall. Repeat a second trial.	<ul style="list-style-type: none"> <li>1) Wind up is initiated with downward movement of hand/ arm</li> <li>2) Rotates hip and shoulders to a point where the nonthrowing side faces the wall</li> <li>3) Weight is transferred by stepping with the foot opposite the throwing hand</li> <li>4) Follow through beyond ball release diagonally across the body toward the nonpreferred side</li> </ul>			
					<b>Skill Score</b>	

## APPENDIX B

Edith Cowan University

School of Biomedical and Sports Science

### Summary of Study

The study being conducted is looking at head stabilisation in the fundamental skill of overarm throwing. The results of the study will go a long way into understanding how children perform the skill and the visual factors that affect the performance.

The procedure of the study will include:

1. A performance based motor ability test carried out by a consultant with 5 years experience in administering these tests.
2. Marking the children with reflective balls at specific joints using micropore tape.
3. A Video recording of 2 throws.
4. Computerisation of the throws into a digital format.
5. Statistical analysis of the throws across each subject and across each condition.
6. All children will wear a lightweight bicycle helmet with reflective markers to simulate head-position.

The video filming session will take approximately ½ an hour and will be conducted in a laboratory setting at the University.

The upmost care will be taken during the study and names of the children will not be used when the results are published.

Results of each child will also be available for the child and/or their parent/guardian to view.

The strictest confidentiality will be maintained at all times.

Thank-you

APPENDIX C

Edith Cowan University  
School of Biomedical and Sports Science

**Head Motion in Overarm Throwing for Children with Varying Levels of Motor Proficiency**

By  
Kevin Netto  
Bachelor of Science (Hon) Sports Science

**Form of Disclosure and Informed Consent**

I, \_\_\_\_\_ (Participant's Parent/Guardian) have read the summary sheet provided and any questions I have asked have been answered to my satisfaction.

I agree to allow \_\_\_\_\_ (Participant's Name) to participate in the study.

I agree that the research data gathered for this study may be published provided my child's/ward's name is not identifiable.

Signature: \_\_\_\_\_  
(Participant's Parent/Guardian)

Date: \_\_\_\_\_

Signature: \_\_\_\_\_  
(Researcher)

Date: \_\_\_\_\_