Head stabilisation during running in place of children with varying motor proficiency levels

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Head Stabilisation During Running in Place of Children with Varying Motor Proficiency Levels

By

Craig Atkins

A Thesis Submitted in Partial Fulfilment of the Requirements for the Award of Bachelor of Science (Sports Science) Honours.

At the School of Biomedical and Sports Sciences, Edith Cowan University, Joondalup.
USE OF THESIS

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

Understanding head motion in children may contribute to development of effective strategies to improve coordination of children. The purpose of this study was to investigate head motion in children during stationary running. Twelve healthy 8-year-old children participated in this study and underwent a running proficiency test based on the Test for Gross Motor Proficiency (TGMD). Subjects were then videotaped while running for one minute “on the spot”. Reflective markers were digitised for analysis of head motion relative to the external environment, and relative to the trunk.

Resultant and component head angular velocities were calculated for each subject over five consecutive stride cycles. The relationship between these head movement variables and running proficiency was also investigated. Independence of head and trunk movement was also investigated to determine whether joint independence is an invariant characteristic of running skill proficiency. Temporal characteristics of head angular velocity profiles were also compared to investigate the consistency of head stabilisation for each subject.

Research indicated that head stabilisation of all children during running in place was sufficient to maintain maximum possible quality of visual and vestibular information used for development of running skill. No significant relationship was found between head angular velocity and running proficiency, although one low proficiency subject exhibited consistent head stabilisation patterns across five stride cycles.

Head stabilisation of the participants in this study was found to be well within the limit of reliability for visual and vestibular information. The timing of head stabilisation during the stride cycle was inconsistent for all running proficiency levels, and further investigation is necessary to validate these findings, particularly for subjects with low motor skill proficiency.
DECLARATION

I certify that this thesis does not incorporate without acknowledgment 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 27/3/08
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Finally, I extend belated apologies to my family, in particular my mother who had to suffer and put up with me all year. I could not have completed this thesis without the mix of sympathy and motivation from my friends, who all tried to understand my state of mind. I know I am not alone in being proud of my achievement.
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CHAPTER ONE

Introduction

Effective development of fundamental gross motor skills is of primary importance during childhood. Most skills used in sport and complex movement activities are advanced applications of fundamental gross motor skills (Walkley, Holland, Treloar, Probyn-Smith, 1993). The skills of walking, running, throwing, catching and striking are classified as fundamental motor skills.

Development of fundamental gross motor skills by the age of seven is considered possible for all children without disabilities (Wickstrom, 1983). It is widely acknowledged that fundamental gross motor skills are developed in a sequential manner (Walkley, et al., 1993; Ulrich, 1985), and a wide range of tests of motor proficiency have been developed in an attempt to quantify development of these skills in children. One such test is the “Test for Gross Motor Development” (TGMD) (Ulrich, 1985). A primary use of this test is to serve as a ‘measurement instrument’ for gross motor development. The TGMD involves observation of presence or absence of critical elements of fundamental movement patterns, and accordingly a numerical score of fundamental gross motor skill proficiency can be obtained.

Development of motor control in children is indicated by a trend toward increasing consistency in movement planning and motor programming (Williams, Woollacott & Ivry, 1992; Beuter, Duda & Widule, 1989). This implies that measurement
of movement consistency can be indicative of motor skill proficiency levels of children. A specific example of this statement is that a significant element of this process of skill improvement is learning to use visual information more effectively (Robertson, Collins, Elliott, Starkes, 1994). Accordingly, it is reasonable to suggest that the consistency of head movement may be significantly related to the level of development of fundamental gross motor skills.

The importance of the head during development of fundamental gross motor skills is justified further, since the head contains the visual and vestibular systems that are the two most important perceptual systems for detection of self-motion relative to space (Pozzo, Berthoz & Lefort, 1990). A major function of the visual and vestibular systems is to provide intrinsic feedback related to skill performance (Schmidt, 1991).

The input of vestibular and visual information, or intrinsic feedback, is a significant influence in learning fundamental gross motor skills. The two methods in which intrinsic feedback is delivered are 'closed loop' and 'open loop' feedback. 'Closed loop' feedback refers to corrections made during skill execution and 'open loop' feedback refers to corrections made to motor programs for subsequent skill execution. It is important that a reliable ongoing movement correction, or closed loop system accompanies a central planning, or open loop system (Proteau, Tremblay & DeJaeger, 1998). The reliability or quality of visual and vestibular information during skill performance is a significant factor in development of motor skill proficiency.
The quality of visual and vestibular information is significantly influenced by angular velocity of the head. It is widely reported in the literature that vestibulo-ocular reflex (VOR) function deteriorates for head angular velocities in excess of $350^\circ s^{-1}$ (Pozzo et al., 1989; Robertson et al., 1994; Riach & Starkes, 1989; Laurent & Thomson, 1988). Actual peak values and the time during the stride cycle spent above and below the VOR functional threshold may provide information related to the demand for VOR information at a particular level of running proficiency. Excessive movement of the head in children produces more complicated proprioceptive information (Riach & Starkes, 1989). Head stabilisation is operationally defined as periods of decreasing head angular velocity (Pozzo et al., 1989). Poor head stabilisation may limit the development and retention of fundamental gross motor skills.

Head stabilisation may be more important for children with low motor skill proficiency than for skilled children. This is supported by the necessity for high quality and quantity of afferent information during early stages of skill development (Proteau et al., 1998; Robertson et al., 1994). Effective head stabilisation can maximise the potential level of fundamental gross motor skill proficiency by providing high quality visual and vestibular information during skill development.

It is important to develop fundamental gross motor skills effectively, since most skills used in sports and movement activities are either advanced applications or combinations of fundamental motor skills (Walkley et al., 1993). Running is a fundamental motor skill (Frost, Bar-Or, Dowling & White, 1995) and has been selected
for focus of this study. Effective development of running skill allows children to participate in, and develop more complex movement skills.

Children normally develop fundamental motor skills in a sequential and orderly manner (Walkley et al., 1993; Scholz & Kelso, 1989). Therefore, it is reasonable to suggest that important movement components in the fundamental skill of running are also developed in a similar manner. Identification of patterns of head movement during running skill acquisition may provide information related to the development of specific motor programs for running.

There has been little research of head movement during the development of running in children. Kinematic analyses of head movement have been included in a number of studies (Robertson et al., 1994; Pozzo et al., 1990; Riach & Starkes, 1989; Keshner & Chen, 1996), but none have investigated changes in head movement with improving skill of running in place (Okuzumi, Tanaka, Haishi, 1997). Accordingly the purpose of this study was to investigate head motion in children during stationery running.

Figure 1 on the following page represents the theoretical basis for this study. Head stabilisation that occurs to service the demands of the vestibulo-ocular reflex (VOR) is the primary focus for investigation. Angular velocities of the head as a result of perturbations transferred from foot impact are considered to be consistent for all subjects, and are not considered in this study.
Importance of movement of the head has been established in a number of studies (Robertson et al., 1994; Riach & Starkes, 1989; Pozzo et al., 1990), and is considered particularly important because the head contains the two major systems for provision of intrinsic feedback (the visual and vestibular systems). The timing of peak head angular velocities during the stride cycle is important since presence of invariant patterns of head angular velocities across stride cycles may indicate the existence of central motor programs for controlling head motion during running (Winter, 1983).

It is important to investigate characteristics of head stabilisation adopted by children during development of running. Assessment of angular velocity of the head with respect to the external environment can provide information about the demand for reliable visual and vestibular information during the stride cycle. Periods in which head angular velocity exceeds the functional threshold of the VOR indicate that visual and vestibular information cannot be used. Analysis of head and trunk movement can provide an indication of whether head motion is a response to trunk movement as a link in the kinetic chain, or whether the head moves independently of the trunk to optimise sensory information.
Perhaps there are characteristic patterns of head stabilisation which correspond to particular levels of running proficiency, including variation in the duration and timing of head stabilisation. Identification of characteristic patterns of head stabilisation may indicate the presence of motor programs during running skill acquisition. The research questions in the following section have been developed to determine if the head is deliberately stabilised to maximise the quality of visual and vestibular information during early stages of running development. If invariant characteristics of head stabilisation can be identified, more effective education and intervention strategies for teaching fundamental skills such as running may be developed.

**Research Questions**

1. Does head angular velocity during running in place exceed the functional limits of the VOR?
2. Is there a significant relationship between head angular velocity and running proficiency?
3. Does head movement occur as a response to foot perturbation as part of a kinetic chain, or independently of the trunk to optimise sensory input?
4. Is the timing of resultant and component head angular velocity maximum values an invariant characteristic of particular running proficiency levels?
Limitations

There are a number of possible limitations and factors that affect the external validity of findings of this study. The specificity or generality of a running proficiency test is a concern associated with application of any chosen running proficiency test. This is a difficult limitation to address, since most motor skill tests have specific skills and drills used for assessment, or focus specifically on some body segments at the expense of others. The TGMD is widely used for assessment of fundamental gross motor proficiency, and the adaptation of the TGMD shown in Appendix A ensure that the running proficiency test is appropriate for this study.

Subjects were allowed to run at their preferred stride frequency during the running trial. Variation in preferred stride frequency between subjects and within trials could be a confounding factor in angular head movement. After conducting a pilot study, it was decided to allow subjects to run at their preferred stride frequency, since previous studies of walking and running in which preferred stride frequencies were selected by subjects resulted in low variation in head angular velocity (Holt, Fang Jeng, Ratcliffe, Hamill, 1995). The alternative methodology to fix stride length or stride frequency may affect the subjects’ preferred running technique.

Subjects were also instructed not to undertake a visual fixation strategy. The absence of a visual fixation target may reduce the motivation for head stabilisation (Keshner & Chen, 1996), and leaves potential for random head movement unrelated to
stabilisation and skill demands. It is considered that these two performance conditions discussed above may alter subjects’ natural running patterns, particularly for subjects with lower running proficiency levels. A major aim of this study was for subjects to apply their ‘natural’ running technique by minimising potentially prohibitive task demands.

Subjects were randomly sampled from Perth primary schools. The subject group used in this study was delimited to 7 male and 5 female 8-year-old children. Statements and implications of this study cannot be readily applied to the general population, and further studies are necessary to confirm and validate any findings related to a wider range of children.

**Definition of Terms**

**Motor skill/running proficiency**
- presence or absence of technical elements of running
- measured by application of a checklist including TGMD and additional points during a specific running proficiency test

**External reference frame**
- set of orthogonal axes in space to assess movement relative to the external environment

**Trunk reference frame**
- set of orthogonal axes calculated from specific joint locations to assess head movement relative to the trunk of the subject
Somersault: motion of the head or trunk about its mediolateral axis

Tilt: motion of the head or trunk about its anteroposterior axis

Twist: motion of the head or trunk about its longitudinal axis

Stride Cycle: period from right foot plant to subsequent right foot plant characterised by peaks in hip vertical acceleration
CHAPTER TWO

Review of Literature

Figure 2 below is a model of the structure of this chapter. A brief description of the figure is included below, followed by the full literature review.

![Diagram of Importance of Head Stabilisation]

The review of literature will introduce the importance of head stabilisation, by firstly providing a working definition of head stabilisation, and secondly discussing reasons why it is important. A discussion of literature reporting the functional limitations of the VOR will be followed by a section related specifically to the benefit of provision of a low complexity VOR signal in terms of assisting fundamental gross motor skill
acquisition. A discussion of motor control literature with specific application to running follows discussion of the model.

Definition of Head Stabilisation

Head stabilisation is defined as occurring when the magnitude of angular velocity of the head is small. Consequently, small resultant angular velocities of the head during locomotion indicate that the head is stabilised effectively. Pozzo et al. (1989) applied this definition of head stabilisation. Accordingly, this convention has been applied in the present study and serves as a platform for the development of research questions and selection of variables to be analysed.

Importance of Head Stabilisation – Reduce Complexity of VOR Signal

Head stabilisation is particularly important during early stages of fundamental skill development, because complexity of the visual and vestibular signal is reduced to ensure that the VOR is functional for the maximum duration of skill performance. The importance of head stabilisation in maximising quality of visual and vestibular information is widely supported (Pozzo et al., 1989; Grossman, Leigh, Abel, Lanska, Thurston, 1988; Holt, Jeng, Ratcliffe et al., 1995; Riach & Starkes, 1989; Keshner & Chen, 1996).
Purpose of Head Stabilisation – VOR Functional Limit

Both the vestibular and visual apparatus have a functional limit. If skill parameters exceed these functional limitations the information and feedback from VOR is unreliable or unavailable. Information from the VOR is considered ineffective for head angular velocities greater than 350°s\(^{-1}\) (Pozzo et al., 1989, p. 587). During skill performance, adjustments must be made to ensure functional limits of feedback mechanisms such as the VOR are not exceeded. Accordingly, the head must be effectively stabilised to ensure that angular velocities of the head do not exceed 350°s\(^{-1}\) which will ensure constant availability of reliable visual and vestibular information.

Simplification of VOR Signal - Benefits of Effective Head Stabilisation

There are significant benefits of reducing complexity of the VOR signal. The high quality information obtained by the VOR at low head angular velocities provides high quality feedback for unskilled performers during development of fundamental skills. Both postural stability and dynamic balance of the head during running are important factors in provision of effective VOR information.

Postural stability both affects and is affected by effective function of the VOR. Accordingly, it is important to stabilise the head effectively to maintain postural control, which will enable children full capacity to effectively visually fixate. Head stabilisation is regarded as an important part of the postural control system (Pozzo et al., 1990). Poor
postural stability is considered to contribute largely to the inability of children to visually fixate, which is a hindrance to visual proprioception (Riach & Starkes, 1989; Sveistrup, Burtner & Woolacott, 1992). Therefore, postural stability and VOR function are dependent on each other, and poor function of either has a "vicious cycle" effect.

Effective head stabilisation is considered particularly important during dynamic balance tasks, such as running, due to the heavy reliance on the vestibular apparatus (Robertson et al., 1994). It is important that the quality of visual and vestibular information is sufficiently high when necessary, particularly during stages of skill acquisition when vision is considered to be particularly important (Hollands, Marple-Horvat, Henkes, Rowan, 1995; Holt et al., 1995).

Running & Motor Control

This section will discuss three major issues developed from literature related to running and motor control; the expected demand for visual and vestibular information during running in place, the development of joint independence with increasing running proficiency, and timing of head stabilisation during the running stride cycle.

According to previous studies, the VOR can comfortably accommodate visual and vestibular demands during running in place (Pozzo et al., 1990; Grossman et al., 1988). This indicates that head stabilisation during running in place has been found to maintain head angular velocity profiles below the VOR functional threshold. Subjects in these
studies were ‘mature form’ runners, and the capacity for head stabilisation to adequately meet VOR demands has not been investigated for varying levels of running proficiency.

Running proficiency is also reflected by the independence of joint movement, which is commonly referred to as “degrees of freedom” of movement (Vereijken, van Emmerik, Whiting & Newell, 1992; Whiting & Vereijken, 1993). A high level of joint independence is indicative of a high level of running proficiency, whereas children with low levels of skill proficiency often minimise head kinematics by “locking” of the head-trunk system (Pozzo, Berthoz & Lefort, 1990) and exhibit similar head and trunk movement profiles during the stride cycle.

The timing of visual sampling during the running stride cycle is widely considered to be more important than the duration of visual sampling (Hollands et al., 1995; Holt et al., 1995; Laurent & Thomson, 1988). Since the quality of visual information is influenced by the angular velocity of the head, the timing of good head stabilisation (low angular velocity) may indicate periods in a stride cycle where visual sampling is most important. For example, the time immediately prior to footstrike during the stride cycle is considered to demand the highest quality visual information (Hollands et al., 1995). The implication of the importance of timing of visual sampling is that children with low proficiency levels may exhibit poor head stabilisation during important events in the stride cycle, and as a result, receive poor quality visual and vestibular information when the highest quality is most necessary.
Summary of Literature Review

Head stabilisation is indicated by low angular velocity of the head during skill performance. The head contains both the visual and vestibular apparatus which are primary sources of information for modification of performance by closed and open loop mechanisms. Head stabilisation reduces the complexity of information from the VOR and maximises the duration in which VOR information remains reliable and effective. Information from the VOR is considered unreliable for head angular velocities in excess of $350^\circ\text{s}^{-1}$.

The two major benefits of reducing the complexity of the VOR signal with effective head stabilisation are postural stability and dynamic balance. Poor postural stability is considered to hinder the capacity of children to visually fixate. Reliance on visual information during early stages of skill development is high, which implies that head stabilisation is particularly important for children at low fundamental skill proficiency levels. A high level of dependence on vestibular information during dynamic balance tasks such as running ensures that simplification of the VOR signal is highly beneficial.

Studies of mature form runners indicate that VOR demands are easily accommodated during running in place, but investigation of this suggestion specifically for children with low running proficiency levels is necessary. Independence of trunk and head movement should also reflect the level of running proficiency since an increase in
degrees of freedom of movement is a common indicator of increasing skill proficiency. The importance of maintaining low head angular velocity in service of VOR demands is matched, if not exceeded, by the necessity for effective timing of head stabilisation. It is widely considered that the timing of visual sampling is a primary concern. Since high quality visual and vestibular information is essential for children with low running proficiency, the timing of head stabilisation during the stride cycle may be indicative of running proficiency levels.
Twelve 8-year-old children were randomly sampled from Perth primary schools to participate in this study. The subject group consisted of 7 males and 5 females. Eight-year-old children were selected for a number of reasons.

- Eight-year-old children have a wide range of running proficiency levels (Raudsepp & Paasuke, 1995).
- Anthropometric variation between 8-year-old subjects is not as great as for subjects around the age of puberty. Accordingly, differences between running technique are generally not attributed to anthropometric variation.
- Since the children are pre-pubertal, co-ordination differences cannot be attributed to differences associated with rapid growth rates (Raudsepp & Paasuke, 1995).

Subjects diagnosed with learning disorders, physical impairments or other medical conditions directly affecting running performance were not considered for participation in the study. Sampling of subjects was conducted through correspondence with a contact in the education system in the Joondalup area. Restriction of the sample by confining selection of children to the Joondalup area was for the convenience of the subjects.
A consultant with previous experience in motor skill testing recruited subjects and conducted a running proficiency test based on the TGMD. The sole purpose of this test was to provide a quantitative measure of the motor coordination level of the subjects. Even though reliability is a concern when using only one consultant, the limited number of consultants with experience in using the TGMD, and the time constraints of thesis preparation resulted in one consultant testing subjects. The running proficiency assessment was recorded using a checklist (Appendix A).

**Variables Selected for Analysis**

Variables related to head movement were calculated about three axes in a right hand coordinate system with respect to both the external reference frame (ERF) and the trunk reference frame (TRF). The variables selected for analysis are based on the theoretical framework described in Figure 3 below, and rationale for their selection is provided in the following section.

![Figure 3](image.png)

**Figure 3.** Selection of variables to measure head stabilisation.

The magnitude of maximum resultant and component angular velocity was calculated to address Research Question 1. Pearson product moments of the variables
listed below were conducted to determine whether head angular velocities were significantly related to running proficiency as indicated in Research Question 2. Research Question 3 refers to independence of head movement with respect to the trunk, and is investigated by direct comparison between resultant head and trunk angular velocity with respect to the external reference frame. Research Question 4 is investigated by identifying the timing of maximum angular velocity during the stride cycle. The temporal characteristics of angular velocity profiles may be indicative of particular running proficiency levels.

The variables listed below will be assessed in this study. It is important to determine whether these variables are related to running proficiency using a between subject comparison, and also to determine whether consistency of the quantity or timing of head movement during the stride cycle are invariant characteristics of running proficiency level using a within subject comparison.

- Maximum and minimum resultant head angular velocity
- Maximum component head angular velocities
- Comparison across trials within subjects of the magnitude of resultant and component maximum head angular velocity values (with respect to both the ERF and TRF)
- Comparison across trials within subjects of the timing of resultant and component head angular velocity (with respect to the trunk)
- Duration of head resultant angular velocity above $350\,\text{°s}^{-1}$ – the functional threshold of reliable ocular information (Pozzo, Berthoz & Lefort, 1989)
Angular velocities of the head were calculated with respect to the external reference frame, and also with respect to the trunk reference frame. Figure 4 represents the purpose for analysis of head movement with respect to both the external and trunk reference frames.

Figure 4. Selection of reference frames for analysis of head stabilisation.

**Rationale for Variable Selection**

Analysis of head angular velocity with respect to the external reference frame is included in this study to provide information about the relative demand for reliable VOR feedback during the running stride cycle. The timing of periods during the stride cycle above and below the functional threshold of the VOR can provide information related to the demand for reliable visual and vestibular information. Patterns of effective head
stabilisation, characterised by periods of low head angular velocities with respect to the external reference frame, may vary depending on the level of running proficiency.

Calculation of head angular velocity with respect to the trunk provides an indication of the independence of joint movement. High angular velocities of the head with respect to the trunk indicate that the head is moving independently of the trunk. Previous studies indicate that subjects with low running proficiency “lock” the head to the trunk (Pozzo, Berthoz & Lefort, 1990), and subjects with a high level of running proficiency exhibit highly independent joint movement (Vereijken et al., 1992; Jensen, Thelen et al., 1995; Whiting & Vereijken, 1993).

Maximum values of component and resultant head angular velocities were calculated to determine if there was a significant relationship between the magnitude of head stabilisation and running proficiency level. Calculation of head angular velocities with respect to the external reference frame provides information related to service of the demands of the VOR during running performance, whereas head angular velocity with respect to the trunk provides information regarding the independence of head and trunk movement.

Between and within subject comparison of head angular velocity profiles during the stride cycle allowed investigation of possible invariant characteristics of head stabilisation that may be typical of running proficiency levels. Invariant elements of head angular velocity profiles may be indicative of a specific motor program for head
stabilisation during running in place for participants of all proficiency levels. Selection of variables was based entirely on investigation of the research questions raised in Chapter One.

**Equipment**

The equipment listed below was required for this study.

- Calibration frame consisting of eight reflective spherical points in known locations in space for calibration prior to data analysis,
- IBM PC computer, TV monitors and Ariel Performance Analysis System (APAS) automatic digitising software,
- Spherical reflective digitising markers (x6) attached to anatomical landmarks for calculation of trunk and head reference axes systems (Figures 5 and 6),
- A loose spherical reflective ball used as a synchronisation cue following each running trial,
- Variable shutter speed 8mm Panasonic video cameras – sampling rate 50 fields per second (x6), each with tapes, tripods and power supplies. These cameras were placed surrounding the trial area, and cameras were zoomed and focused to capture the entire subject. Cameras were placed as far away from subjects as possible to minimise systematic error.
- Portable lighting (100W) set up on tripods next to cameras to illuminate reflective markers more effectively.
• Skull cap with attached three reflective digitising markers (in blue) required to assess head movement about longitudinal, mediolateral and anteroposterior axes (Figure 5)

![Front View](image1)
![Side View](image2)

**Figure 5.** Front and side profile of skull cap.

The three superior markers on the skull cap in Figure 5 were used for digitising to define a plane approximately parallel to the Frankfort plane. The Frankfort plane is widely used to approximate the location and orientation of the vestibular apparatus located in the inner ear (Pozzo, Berthoz, Lefort, 1990). These markers enabled 3D analysis of head movement and calculation of an axis system for analysis of head rotation about 3 axes. Studies investigating head movement use the Frankfort plane because of the proximity and similarity of orientation to the vestibular balance apparatus located in the middle ear (Pozzo, Berthoz & Lefort, 1990).
Data Collection

A consultant with expertise in application of the TGMD conducted a running proficiency test and completed a running skill checklist (Appendix A) for each subject prior to video recording. Subjects participated in the running trial in random order.

Video cameras, lights and mountings required for data collection were set up prior to actual data collection sessions. Actual data collection sessions commenced with subjects participating in a brief outdoor run of 25m to enable assessment of their running proficiency level as previously discussed. Reflective spherical markers were then attached to subjects approximating the following anatomical and external landmarks (refer to Figures 5 and 6).

- Right Hip
- Xiphoid Process
- Right Frankfort
- Left Hip
- Mid Occipital
- Left Frankfort

Maximum duration of the recorded running trial was set at 1 minute. The subject was instructed to run as ‘normally’ as possible while attempting to maintain position on the spot. No additional instructions were provided. The trial was terminated earlier than the one-minute deadline if the subject experienced difficulty or voluntarily ceased running. After sufficient footage had been collected, subjects were instructed to run forward out of the recording area, to allow the synchronising reflective ball to be thrown into the filming area.
Data Analysis

Video footage obtained during running trials was captured on computer using a Matrox capture card. At this stage, trials in which a flight phase could not be clearly visually identified during all stride cycles were excluded from data analysis. An Ariel Performance Analysis System (APAS) was used to edit video footage and digitise the spherical reflective balls corresponding to joint landmarks. Inaccurate and disjointed data obtained from the APAS automatic digitising system were interpolated and corrected where necessary.

Raw co-ordinate data were smoothed using a Butterworth second order filter at an optimal cut-off frequency. This optimal cut-off frequency was selected by the APAS software based on an analysis of residuals. The optimal cut-off frequency was commonly between 4 and 6 Hertz. Local peak vertical accelerations of the right and left hips were used to define and separate five consecutive single stride cycles for each subject, in a method similar to that applied by Ulrich, Schneider, Jensen, Zernicke, Thelen (1994). These stride cycles were then confirmed by checking the original video footage.
Head motion with respect to the trunk about each axis was quantified using geometrical techniques to approximate trunk reference axes. The marker points listed below were used to locate the trunk reference axes (right column), and head movement (left column) relative to these axes. The three points applied to approximate the trunk axis reference system are shown in Figure 6.

- Mid Occipital
- Right head marker
- Left head marker
- Xiphoid Process
- Right Hip axis
- Left Hip axis

Figure 6. Anatomical markings applied for calculation of trunk reference axis system.

Geometrical calculation of a three-axis orthogonal trunk reference system allowed analysis of head movement relative to the trunk. This enabled assessment of head movement allowing for confounding vertical oscillation of the head caused by
perturbations during foot contact while running. The major purpose of analysis with respect to the trunk was to indicate if head movement occurs independently of the trunk.

The axes of rotation specified for the trunk and head co-ordinate systems used in this study are represented in Figures 7 and 8, and were derived using methods similar to Areblad, Nigg, Ekstrand, Olsson, Ekstrom (1990). These axes of rotation were applied to calculate angular velocities of the trunk and head with respect to the external reference system (i.e. motion relative to a fixed point in space).

Figure 7. Trunk reference system axes of rotation.

Figure 8. Head reference system axes of rotation.
The longitudinal axis of the head cannot be shown in Figure 8, and is perpendicular to the x and y axes shown.

The change in angle about each axis of rotation in Figures 7 and 8 were calculated by application of the following formulae to raw coordinate data using a FORTRAN program (Sanders, 1999). Calculations were applied during the time interval between \( n-1 \) (one frame before), and \( n+1 \) (one frame after), centred about frame \( n \). These formulae were applied for the trunk axis system in Figure 7, and for the head axis system in Figure 8.

\[
\Delta \alpha \text{ (transverse axis)} = 90^\circ - \arccos \left[ Z_{t(n-1)} \cdot (Z_{t(n+1)} \times X_{t(n-1)}) \right]
\]

\[
\Delta \beta \text{ (anteroposterior axis)} = 90^\circ - \arccos \left[ Z_{t(n+1)} \cdot X_{t(n-1)} \right]
\]

\[
\Delta \theta \text{ (longitudinal axis)} = 90^\circ - \arccos \left[ X_{t(n+1)} \cdot (Z_{t(n+1)} \times X_{t(n-1)}) \right]
\]

where: 
- \( Z \) the unit vector in the calculated z direction
- \( X \) the unit vector in the calculated x direction
- \( \times \) calculation of the cross product of two vectors
- \( \cdot \) calculation of the dot product of two vectors
Angular velocity was then calculated by multiplication of the changes in angle by half of the camera sampling rate (50 frames per second).

\[
\begin{align*}
\text{Somersault Velocity} &= \Delta \alpha \times \text{sampling rate} / 2 \\
\text{Tilt Velocity} &= \Delta \beta \times \text{sampling rate} / 2 \\
\text{Twist Velocity} &= \Delta \theta \times \text{sampling rate} / 2
\end{align*}
\]

Positive directions of each component angular velocity are indicated in Figure 9 below. The positive directions were determined as part of a pilot study to confirm the accuracy of the FORTRAN program (Sanders, 1999). All angular velocities calculated were normalised to percentile values using an interpolating spline function. Start and endpoints of each stride cycle were defined as indicated previously in this chapter.

Figure 9. Positive directions of component angular velocities.
Head motion with respect to the trunk was calculated by transformation of 3D coordinates of the head so that they were expressed relative to the trunk axis system.

**Reliability of Digitising Procedure**

To determine the reliability of the digitising procedure and software, a single running trial was digitised using the APAS software on five separate occasions. The data for each digitising attempt was processed as per the methodology outlined in the data analysis section. The mean and standard deviation of resultant and component angular velocities for each normalised stride time were calculated. These values were used to compute a 95% confidence interval for each angular velocity component representing the reliability of the results of this study. A sample confidence interval, and the reliability of calculated resultant and component head angular velocities is reported in Table 1 in the following chapter.
CHAPTER FOUR

Results

This chapter is structured in accordance with the research questions in Chapter One. An assessment of the reliability of the digitising procedure will be followed by explanations of results related to each research question.

Reliability of Digitising Procedure

A single trial was digitised five times using the APAS software to measure the reliability of the digitising process. The mean and standard deviation of the five digitising attempts was calculated, and a 95% confidence interval is shown in Figure 10.

![Reliability - 95% Confidence Interval (Resultant Head Angular Velocity wrt ERF)](Image)

Figure 10. 95% Confidence Interval to measure Reliability of Digitising Procedure.
The confidence interval represented in Figure 10 indicates that calculation of maximum resultant head angular velocity values with respect to the ERF are reliable to approximately within \( \pm 10^\circ\text{s}^{-1} \). Confidence intervals were calculated for component and resultant head angular velocities with respect to both the ERF and TRF and are included below in Table 1.

**Table 1**

95% Confidence Intervals for Component Head Angular Velocities wrt to the ERF & TRF

<table>
<thead>
<tr>
<th>Variable</th>
<th>Range of 95% Confidence Interval (angular velocity in degrees/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERF Somersault Component</td>
<td>( \pm 12.1 )</td>
</tr>
<tr>
<td>ERF Tilt Component</td>
<td>( \pm 7.9 )</td>
</tr>
<tr>
<td>ERF Twist Component</td>
<td>( \pm 13.2 )</td>
</tr>
<tr>
<td>ERF Resultant</td>
<td>( \pm 10.8 )</td>
</tr>
<tr>
<td>Head wrt Trunk Somersault Component</td>
<td>( \pm 5.2 )</td>
</tr>
<tr>
<td>Head wrt Trunk Tilt Component</td>
<td>( \pm 4.4 )</td>
</tr>
<tr>
<td>Head wrt Trunk Twist Component</td>
<td>( \pm 7.2 )</td>
</tr>
<tr>
<td>Head wrt Trunk Resultant</td>
<td>( \pm 8.5 )</td>
</tr>
</tbody>
</table>

**Running Proficiency & Maximum Angular Velocities – Research Questions 1 and 2**

Table 2 below contains summary data of run proficiency, and maximum angular velocities for participants in this study. Run proficiency was measured using the checklist adapted from the TGMD (refer Appendix A), and maximum angular velocities are resultant values, representing a maximum overall value over five consecutive strides.
Table 2
Run Proficiency & Maximum Resultant Angular Velocities

<table>
<thead>
<tr>
<th>Subject</th>
<th>Run Proficiency (10)</th>
<th>Max Angular Head Velocity (°s⁻¹)</th>
<th>Max Angular Trunk Velocity (°s⁻¹)</th>
<th>Max Angular Head Velocity (wrt Trunk) (°s⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>183.2</td>
<td>115.3</td>
<td>199.9</td>
</tr>
<tr>
<td>2</td>
<td>10</td>
<td>114.5</td>
<td>240.2</td>
<td>254.6</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>155.5</td>
<td>119.5</td>
<td>132.7</td>
</tr>
<tr>
<td>4</td>
<td>8</td>
<td>216.2</td>
<td>300.4</td>
<td>176.2</td>
</tr>
<tr>
<td>5</td>
<td>3</td>
<td>98.4</td>
<td>114.5</td>
<td>144.0</td>
</tr>
<tr>
<td>6</td>
<td>9</td>
<td>136.3</td>
<td>94.7</td>
<td>153.0</td>
</tr>
<tr>
<td>7</td>
<td>7</td>
<td>89.7</td>
<td>204.1</td>
<td>210.0</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
<td>97.8</td>
<td>111.2</td>
<td>146.3</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
<td>118.8</td>
<td>179.7</td>
<td>162.7</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>105.4</td>
<td>103.5</td>
<td>132.8</td>
</tr>
<tr>
<td>11</td>
<td>10</td>
<td>210.5</td>
<td>142.8</td>
<td>205.3</td>
</tr>
<tr>
<td>12</td>
<td>8</td>
<td>16.9</td>
<td>64.8</td>
<td>59.6</td>
</tr>
</tbody>
</table>

Three out of 12 subjects exhibited fully developed running skills and were accordingly awarded a 10 score for the running proficiency test. The lowest running proficiency score was 3 out of 10, and was obtained by two of the 12 subjects. Maximum resultant angular head velocities with respect to the external reference frame (ERF) ranged from 16.9°s⁻¹ to 216.2°s⁻¹. These angular head velocities fall well within the 350°s⁻¹ functional limitation of the VOR.
All subjects showed highest values of maximum resultant angular head velocity with respect to the trunk, with a range from $59.6^\circ \text{s}^{-1}$ to $254.6^\circ \text{s}^{-1}$. None of the three maximum angular velocities in Table 1 were significantly related to running proficiency. Maximum component angular head velocities are represented in Figures 11 and 12.

Figure 11. Maximum component head angular velocities with respect to the external reference frame.
Component Head Angular Velocities - Head wrt Trunk
(degrees/sec)

Figure 12. Maximum component head angular velocities with respect to the trunk.

With the exception of Subject 2, all subjects showed a clearly dominant component of head angular velocity with respect to the ERF (see Figure 11). This dominant component of head angular velocity with respect to the ERF varied among subjects. In almost all cases either the somersault or tilt component was dominant. Maximum component head angular velocities with respect to the trunk (see Figure 12) showed similar characteristics. Maximum angular velocity values for the head with respect to the TRF were generally larger than head angular velocity values with respect to the ERF.

Pearson correlations were calculated between head angular velocity and running proficiency, and indicated that there was no significant relationship between running proficiency and resultant or component head angular velocity. This applied to head motion with respect to both the ERF and TRF. Pearson correlations are reported below in
Table 3. Abbreviations used in Table 3 are as follows; with respect to (wrt) and external reference frame (ERF).

Table 3

Pearson Correlation between Run Proficiency & Maximum Head/Trunk Angular Velocities

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Independent Variable</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run Proficiency</td>
<td>Head wrt ERF – Somersault Component</td>
<td>0.103</td>
</tr>
<tr>
<td>Run Proficiency</td>
<td>Head wrt ERF – Tilt Component</td>
<td>-0.496</td>
</tr>
<tr>
<td>Run Proficiency</td>
<td>Head wrt ERF – Twist Component</td>
<td>-0.292</td>
</tr>
<tr>
<td>Run Proficiency</td>
<td>Head wrt ERF – Resultant</td>
<td>0.384</td>
</tr>
<tr>
<td>Run Proficiency</td>
<td>Head wrt Trunk – Somersault Component</td>
<td>0.164</td>
</tr>
<tr>
<td>Run Proficiency</td>
<td>Head wrt Trunk – Tilt Component</td>
<td>-0.443</td>
</tr>
<tr>
<td>Run Proficiency</td>
<td>Head wrt Trunk – Twist Component</td>
<td>0.329</td>
</tr>
<tr>
<td>Run Proficiency</td>
<td>Head wrt Trunk – Resultant</td>
<td>0.478</td>
</tr>
</tbody>
</table>

All correlations were calculated for a significance level $\alpha = 0.05$. A maximum correlation of 0.478 between running proficiency level and resultant head angular velocity with respect to the trunk indicates that running proficiency is not significantly related to head or trunk angular velocity during running in place.
Independence of Head & Trunk Movement – Research Question 3

Independence of head and trunk movement was investigated by plotting resultant angular velocity profiles for head and trunk angular velocity with respect to the ERF for each subject. A single stride was selected at random for each subject, and an example is shown below in Figure 13. Right foot plants representing the start and finish of a stride cycle occur at 0 and 100 percent normalised stride times respectively, which correspond to the left and right borders of the graph below. Left foot plant occurs at the dotted line corresponding to 50 on the normalised time scale. The same conventions apply to Figure 14.

![Subject 3 - Head v Trunk Angular Velocity](image)

**Figure 13.** Head and trunk resultant angular velocity wrt ERF – Subject 3.
Comparison of head and trunk resultant angular velocities revealed that head movement was independent of trunk movement for subjects of all running proficiency levels, indicated by little similarity between the head and trunk curves. Figure 13 shows the plot of head and trunk resultant angular velocity during a single stride for Subject 3. This subject was the only subject of the 12 that showed some similarity or "locking" between head and trunk movement. All other subjects exhibited random variation of trunk and head movement with little indication of movement interdependence between the head and trunk.

Timing Characteristics of Head Angular Velocity – Research Question 4

Figure 14. Within subject comparison of head movement wrt ERF – Subject 3.
Figure 14 shows the resultant head angular velocity with respect to the ERF for Subject 3, and was the only example of consistency of head movement for all five strides for a single subject. As for Research Question 3, all subjects except Subject 3 showed little consistency of head movement with respect to the ERF or TRF between five strides. As indicated earlier, the magnitude of maximum resultant angular velocity was unrelated to running proficiency level. Similarly, the timing of maximum angular velocities, and the angular velocity profiles of five stride cycles for each subject displayed no significant relationship to running proficiency.

In addition to the graphical methods shown in Figure 14, Pearson correlations were calculated for the five strides collected for each subject. The results indicated that there were no significant within subject consistency for magnitude and timing of peak resultant or component angular velocities. Subjects of all running proficiency levels showed little consistency of head stabilisation patterns during the stride cycle. In addition to head movement and running proficiency showing no significant relationship, there appears to be little evidence of invariant characteristics of head stabilisation at high or low levels of running proficiency.
CHAPTER FIVE

Discussion

This chapter will be structured in accordance with the research questions outlined in Chapter One. A summary of the findings of this study will follow discussion of the research questions. For convenience the research questions are listed below.

1. Does head angular velocity during running in place exceed the functional limits of the VOR?
2. Is there a significant relationship between head angular velocity and running proficiency?
3. Is the independence of head movement with respect to trunk movement significantly related to running proficiency?
4. Is the timing of resultant and component head angular velocity maximum values an invariant characteristic of particular running proficiency levels?

Research Question 1

Visual and vestibular information is effective for head angular velocities below 350°s⁻¹ (Pozzo, Berthoz & Lefort, 1989; Robertson et al., 1994; Riach & Starkes, 1989; Laurent & Thomson, 1988). The maximum head angular velocities found in this study is 216.2°s⁻¹, therefore head stabilisation is sufficient to ensure effective function of the VOR throughout the entire stride cycle during running in place. This finding is replicated in
similar studies with subjects of high running proficiency levels (Pozzo, Berthoz & Lefort, 1990; Grossman et al., 1988). Children of all running proficiency levels appear to have no difficulty maintaining head angular velocities within the functional range of the VOR during running in place.

These findings indicate that children stabilise the head effectively during running in place, by maintaining head angular velocity well below the functional threshold of the VOR. Effective head stabilisation provides the maximum quality of visual and vestibular information during development of the running proficiency.

Research Question 2

Maximum resultant and component head angular velocities were not significantly related to running proficiency level. Even though all subjects comfortably maintained head angular velocity within the functional limit of the VOR, no clear pattern of development of head stabilisation could be found with increasing skill proficiency.

There are a number of possible confounding explanations for the absence of a significant relationship between head stabilisation and running proficiency. Firstly, the running proficiency test based on the TGMD may not be the most effective indicator of running proficiency. Since all angular velocities were small compared to the functional threshold of the VOR it may be the case that running does not cause high head angular velocities for the range of ability of subjects studied in this sample. Either there is little
need for head stabilisation during running in place, or poor runners have already learnt to stabilise the head effectively.

**Research Question 3**

Head and trunk resultant angular velocity was found to be independent for all subjects participating in this study with one exception. Subject 3 clearly exhibited similarity between head and trunk angular velocity profiles during the stride cycle (refer Figure 13). Subject 3 was the least proficient of the subject group, and “locking” of the head to the trunk reduces the degrees of freedom of the head-trunk segment. It is widely acknowledged that degrees of freedom increase with skill proficiency (Vereijken et al., 1992; Jensen, Thelen et al., 1995; Whiting & Vereijken, 1993), and the “locking” strategy employed by Subject 3 to reduce the demand for independent control of the head conforms to this theory. Further investigation of children with low running proficiency levels may indicate whether reduction of the degrees of freedom of the head-trunk system is commonly applied during running in place.

**Research Question 4**

The lowest proficiency runner, subject 3, was again the exception of participants in this study. As indicated in Figure 14, subject 3 exhibited significant consistency of resultant head angular velocity across 5 stride cycles. All other subjects showed little consistency in angular velocity profiles of head resultant angular velocity with respect to both the ERF and TRF.
The timing of maximum resultant and component head angular velocity was not significantly related to running proficiency. The periods during the stride cycle in which the head is stabilised well (and poorly) varies randomly for all subjects except subject 3. This indicates that it is unlikely that there are invariant characteristics of the timing of head stabilisation during running in place. The importance of timing of visual sampling in the stride cycle is well documented (Hollands et al., 1995; Holt et al., 1995; Laurent & Thomson, 1988; Burton & Davis, 1992). Therefore, inconsistency in timing of head stabilisation implies that the quality of visual and vestibular information provided at all stages of the stride cycle is sufficient to meet demand.

However, the consistency shown by subject 3 warrants further investigation, particularly since subject 3 is the lowest proficiency runner, and was the only subject to exhibit “locking” of the head to the trunk as previously discussed. Perhaps the application of a specific motor program for head stabilisation is not necessary during any stage of development of running proficiency. It is likely that subject 3 is reproducing his own pattern of head angular velocity, and it appears to be produced primarily from foot perturbation as a link in the kinetic chain.
Conclusion

Head stabilisation by children during running in place was sufficient to ensure that the functional limits of the VOR were not exceeded at any stage of the stride cycle. Maximum resultant head angular velocities found in this study were well below the $350^\circ s^{-1}$ functional limit for the VOR, therefore the maximum possible quality of visual and vestibular information was available at all stages of the stride cycle.

There was no clearly dominant component of head angular velocity for children during running in place. All subjects, with one exception, exhibited dominant somersault or tilt angular velocity components with respect to the ERF and TRF, and this was expected due to the vertical translation of the head during running in place. Further investigation is necessary to determine the influence of translation of perturbations from foot impact on head angular velocity.

No significant relationship was found between resultant head angular velocity and running proficiency. Similarly, component head angular velocity and running proficiency exhibited no clear relationship. Subjects with the same levels of skill proficiency also exhibited significant variation in between subject comparisons. There appears to be no pattern of development of head stabilisation with increasing running proficiency level.

All subjects moved the head independently of the trunk during running in place, except for one subject with the lowest running proficiency level in the group. Evident
"locking" of the head-trunk system by this subject indicated an attempt to reduce the number of degrees of freedom during running in place. This strategy is expected of subjects with low proficiency levels, and further investigation specifically focusing upon children with low running proficiency levels is necessary to validate this finding.

There was little consistency in timing characteristics of head angular velocity profiles for almost all participants in this study. Again, the lowest running proficiency subject was an exception. The periods in the stride cycle where the head is stabilised well were inconsistent for all subjects. This indicates that it is unlikely that timing of head stabilisation is an invariant characteristic of head movement during running in place. Further investigation of head stabilisation during running in place is necessary, with specific selection of subjects with low running proficiency levels.

Even though head stabilisation was generally found to be unrelated to running proficiency, further investigation is necessary to determine whether head stabilisation patterns are consistent for children with low motor skill proficiency. It is important to clarify whether low proficiency runners exhibit clear "coupling" of the head-trunk system, and whether consistency of head angular velocity profiles is characteristic of children with low motor proficiency.
References


## CHECKLIST FOR RUNNING PROFICIENCY TEST

### Developmental Components

<table>
<thead>
<tr>
<th></th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Arm Swing</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>arms stiff, held high</td>
<td>-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tendency to swing arms outward</td>
<td>-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>swing from elbows</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>elbows flexed approx. at RA</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>swing freely in opposition to legs</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Leg Action</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wide base of support</td>
<td>-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>flexion of support leg at ground contact</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>heel-toe foot contact</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>complete extension of support leg</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>limited forward swing of recovery leg</td>
<td>-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>flexion of recovery leg during forward swing</td>
<td>1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Test for Gross Motor Development (TGMD)

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Yes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flight Phase</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Arms move in opposition to legs, elbows bent</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Foot placement near/on line</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Recovery leg bent 90 degrees</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
APPENDIX B

SUMMARY SHEET

Head Stabilisation in Running

Why are we doing this?

This study is being performed as part of our post-graduate studies. The purpose of this study is to gain a better understanding of head movements of children when they run.

How is the study performed?

Firstly, a consultant will conduct a brief running proficiency test. Reflective markers will then be placed on several sites of each child's body. These sites include their hips and sternum. Each child will then be instructed to run on the spot in the laboratory for a maximum duration of 1 minute.

Video data collection will commence approximately 10 seconds into the trial. The trial will be terminated earlier than the one-minute deadline if the subject experiences difficulty or voluntarily ceases running.

When and where will the study take place?

The study will be conducted over a three-week period until the middle of September. Each child only needs to come in once. Wednesday afternoons 8 and 15 September (1530-1730 hrs) have been set aside for the study. It is anticipated that the total duration of the data collection session will be 10 minutes per child. The study will be carried out at Edith Cowan University's Joondalup campus. The room used will be the Sports Science Department's performance laboratory (Building 17.104). Transportation of children from school to the University can be arranged using a minibus if necessary, and parents will be able to pick them up after the study from the University. Parents are welcome to attend the data collection session.

Other considerations

Male and female research assistants will be available for marker application and assistance during the trial session. All subjects will be treated with the highest level of care and safety. All data will also be stored in a secure place. Video captures and files will be erased immediately after analysis. Subjects' names will not be used in the study or any publication of the findings.

If you agree to participate in the study we will contact you and arrange the best time for you to bring your child in for data collection.

Please return your consent form as soon as possible.
APPENDIX C

CONSENT FORM

Edith Cowan University
School of Biomedical and Sports Science

The Influence of Motor Proficiency on Head Movement in Children During Stationary Running

By
Craig Atkins
In part-time fulfilment of 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.

I realise that I may withdraw my child from this study at any time.

Signature: ____________________________ Date: ____________________________
(Participant’s Parent/Guardian)

Signature: ____________________________ Date: ____________________________
(Researcher)