HEAD STABILISATION DURING RUNNING IN PLACE OF CHILDREN WITH VARYING MOTOR PROFICIENCY LEVELS

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The purpose of this study was to investigate head motion in children during stationary running. Participants in this study underwent a running proficiency test based on the Test for Gross Motor Proficiency (TGMD), and then underwent a one-minute trial of running on the spot while being videotaped. Head stabilisation for all subjects was found to remain well within the functional range of the vestibulo-occular reflex (VOR) and no significant relationship was found between running proficiency and head angular velocity. Proficient subjects moved the head independently of the trunk.

KEY WORDS: head stabilisation, running in place, motor proficiency

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. 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 has been developed in an attempt to quantify development of these skills in children. One 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.
The head in important in the development of fundamental gross motor skills since it contains the visual and vestibular systems. These 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 quality of visual and vestibular information is significantly influenced by angular velocity of the head. It is reported in the literature that vestibulo-occular reflex (VOR) function deteriorates for head angular velocities in excess of $350°s^{-1}$ (Pozzo et al., 1989**;** Robertson et al., 1994; Riach & Starkes, 1989; Laurent & Thomson, 1988).
Excessive movement of the head in children produces more complicated proprioceptive information (Riach & Starkes, 1989). Poor head stabilisation may limit the development and retention of fundamental gross motor skills. 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.
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 stationary running (Okuzumi, Tanaka, Haishi, 1997). The purpose of this study was to investigate head motion in children during stationary running.

METHOD: 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. The running proficiency assessment was recorded using a checklist.
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. Reflective spherical markers were then attached to subjects approximating the following anatomical and external landmarks.

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

Equipment

- 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,
- 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.
- Portable lighting (100W) set up on tripods next to cameras to illuminate reflective markers more effectively.
- Skull cap with three reflective digitising markers attached. These were required to assess head movement about longitudinal, mediolateral and anteroposterior axes (Figure 1).

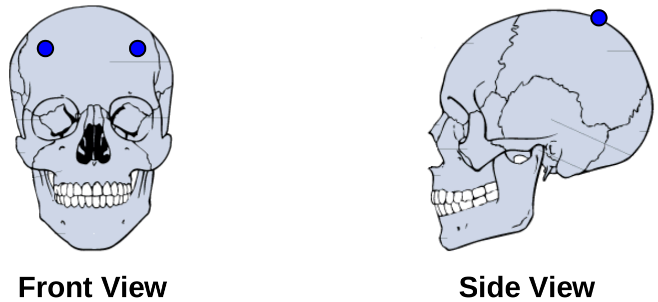

Figure 1 - Front and side profile of marker positions on the skull cap.

DATA ANALYSIS: Video footage obtained during running trials was captured on computer using a Matrox capture card and stored in digital form. 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.

The change in angle about each axis of rotation was 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, and for the head axis system.

$\Delta\alpha$ (transverse axis) $= 90° - \arccos [Z_{(n-1)} \bullet (Z_{(n+1)} \times X_{(n-1)})]$

$\Delta\beta$ (anteroposterior axis) $= 90° - \arccos [Z_{(n+1)} \bullet X_{(n-1)}]$

$\Delta\theta$ (longitudinal axis) $= 90° - \arccos [X_{(n+1)} \bullet (Z_{(n+1)} \times X_{(n-1)})]$

where:
- Z the unit vector representing the longitudinal axis.
- X the unit vector representing the transverse axis.
- $\times$ calculation of the cross product of two vectors
- $\bullet$ 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).

RESULTS: 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$^{o}s^{-1}$ to 216.2$^{o}s^{-1}$. These angular head velocities fell well within the 350$^{o}s^{-1}$ functional limitation of the VOR. Maximum angular velocity values for the head with respect to the trunk reference frame (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. 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 angular velocity profiles. One subject with a low running proficiency 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. 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.

DISCUSSION AND CONCLUSION: Children of all running proficiency levels have no difficulty maintaining head angular velocities within the functional range of the VOR during running in place. Since all angular velocities were small compared to the functional threshold of the VOR, running in place may 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.

Head and trunk resultant angular velocity was found to be independent for all subjects participating in this study with one exception. The least proficient subject of the group exhibited similarity between head and trunk angular velocity profiles during the stride cycle. This '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; Ulrich et al., 1994; Whiting & Vereijken, 1993). This 'locking' strategy may reduce the demand for independent control of the head during early stages of skill development. 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.

The timing of maximum resultant and component head angular velocity was not significantly related to running proficiency. This indicates that it is unlikely that there are invariant characteristics of the timing of head stabilisation during running in place.

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