THE RELATIONSHIP OF THE VESTIBULAR AND PROPRIOCEPTIVE SYSTEMS TO DYSFUNCTION IN VERTICALITY PERCEPTION, POSTURE AND MOVEMENT, AFTER STROKE

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The extent to which verticality perception influences posture and movement is of considerable importance to the physiotherapist. To determine the relative contributions of the vestibular and proprioceptive systems to visuo-spatial perception after stroke and the relationship of verticality perception to body alignment and utilisation of space during movement, a study was undertaken in the Department of Physiotherapy, University of Queensland.

Forty stroke patients, divided into experimental groups on the basis of quality of verticality perception, were selected for study, while twenty two 'non-stroke' subjects, matched for age and sex, formed a control group. Measurements were taken of proprioception, body alignment, utilisation of space during movement, verticality perception and duration of post rotational nystagmus. Analyses of the correlations between these various modalities revealed those features which are of most significance to the perception of verticality, posture and movement of the stroke patient. From these results, implications for the physiotherapy management of the stroke patient with problems in verticality perception, body alignment and utilisation of space during movement, have been drawn.

The extent to which the quality of verticality perception influences posture and movement is of considerable importance to the physiotherapist. Earlier studies on the quality of verticality perception in the stroke patient have demonstrated that the problem occurs to such a degree and with such frequency that it should be tested in all patients after stroke (Bruell et al. 1956, 1957). The disturbance has been linked with problems in ambulation (Hulicka and Beckenstein, 1961; DeCencio et al. 1970), and it has been suggested that it is a major limiting factor to movement efficiency (Lerner, 1971). It is also considered that resolution of the problem is difficult and, according to Birch et al. (1960), many of the failures in rehabilitation may be related to disturbances in visual orientation. Further, DeCencio et al. (1970), state that the success of a patient's rehabilitation after stroke can be predicted from their verticality scores.

Such findings point to the need for a better understanding of the influence of verticality perception on posture and movement, with particular emphasis on the factors causing the problem in order to resolve or minimise this influence on posture and movement after stroke.

Previous studies have in part led to a better understanding in this area, with the identification of the influence of proprioceptive imbalance on verticality perception. Experimental works have shown that it is with a decrease in visual cues that the postural or proprioceptive framework becomes increasingly important in verticality perception (Witkin and Asch, 1948; Bauermeister, 1964; Bauermeister et al. 1964; Weintraub et al. 1964, and O'Connell et al. 1967). Their studies demonstrated that, while the body remained erect, the removal of visual cues did not alter the accuracy of visual perception. In contrast, the introduction of head or body tilt when visual cues were removed caused significant error of judgement, even in normal subjects. Such workers concluded that an imbalance in somatotopic input can cause an alteration in visual perception of the upright. The influence of the quality of proprioceptive and tactile sensitivity on the accuracy of verticality perception after stroke has been emphasised by the work of Birch et al. (1962), Blane (1962), and McFarland et al. (1962).

Current studies by therapists working in the developmental field have not only identified the importance of integration of proprioceptive and visual systems, but have presented convincing data to demonstrate the importance of the integration of vestibular and visual systems for the development of visuo-spatial skills (Burns and Watter, 1971, 1974; Ayres, 1972; Bullock and Watter, 1978; and Harrison and Bullock, 1978).

Neuroanatomical studies have certainly established that the vestibular and proprioceptive systems, and the vestibular and visual systems interact at a minimum of three levels of the nervous system: in the brain-stem, and at the thalamic and cortical levels.
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The cortical projection of the vestibular system, along with proprioceptive input, allows for regulation of higher postural motor co-ordination through connections with the motor cortex, and for conscious orientation in space, through projection to the inferior part of the parietal lobe (Kornhuber, 1972).

In a report by Grusser and Grusser-Cornelius (1972), the interconnections of the visual and vestibular systems at all levels are described. Within the brain-stem, the extraoculoi nuclei were the site of interaction, while the lateral geniculate body of the thalamus and the visual association cortex, through a relay from the primary vestibular area in the parietal lobe, were the sites of interaction at these higher levels.

The interconnections of the visual and vestibular systems suggest a functionally meaningful interaction of both of these systems. It is suggested by Grusser et al. (1972), that perception of the visual world is continuously under the control of signals from the vestibular receptors. Even with movement of the head or body in space, perceptual constancy occurs. According to Grusser et al., such processing of vestibular and visual signals in the perception of vertical and horizontal direction of visual space is depended on the interconnections of these systems at all levels of the central visual system relay, and not only at the cortical level.

Although problems by verticallity perception (well documented in both Critchley, 1966, and Luria, 1973) have been found to occur with damage to the cortical area that involves a functional interaction between visual, vestibular and proprioceptive information, it has been the work from the development field and neuro-anatomical studies that has pointed to the importance of the vestibular system in visuo-spatial perception.

Available information suggests that a delay in maturation of the vestibular system during development, or faulty input through this system, such as might occur following 'stroke' may give rise to problems in visuo-spatial perception. In the mature nervous system, the cortex exerts an inhibitory influence on both vestibular nuclei discharge and receptor response to vestibular input (Markham, 1972). It is probable that after stroke, this mechanism may be disturbed and such a disturbance is likely to present as an increase in sensitivity of this system, with the receptors in particular becoming more sensitive to position and movement. It is considered that such hyper-sensitivity to posture and motion after stroke could in fact lead to faulty visuo-spatial perception.

The identification of the involvement of both the proprioceptive and vestibular systems in the development of visuo-spatial perception and the interaction of visual, proprioceptive and vestibular systems in maintaining orientation in space, suggests that dysfunction of the vestibular system, along with proprioception problems, may be a factor to consider when problems in verticallity perception present after stroke. The need for study in this area is also supported by the earlier reports of Ettlinger et al. (1957), and McFie and Zangerwell (1960), who suggested that a vestibular disturbance of central type could contribute to problems of spatial perception. However, it would appear from an extensive literature search that studies to demonstrate this relationship have not been conducted.

To determine the relationship between problems in verticallity perception, posture and movement after stroke, and to demonstrate the contribution of proprioceptive and vestibular dysfunction to problems in these qualities, a study was undertaken in the Department of Physiotherapy, University of Queensland.

THE CLINICAL STUDY

In this clinical study, the performance of stroke patients was compared to that of subjects without neurological problems. A structured neurological examination was conducted on all stroke subjects, who were then divided into two experimental groups on the basis of the quality of verticallity perception to enable a comparison of the performance of subjects with and without verticallity perception problems. Experimental group 1 included those stroke subjects with verticallity perception problems, while experimental group 2 subjects were without such problems. A rotation test was used to assess vestibular function, and provided recordings of pre- and post-rotational nystagmus duration for all subjects.

The recordings of all three groups were compared to determine whether the quality of verticallity perception contributed to, or was associated with, problems of posture and movement; and further, whether the quality of proprioception and vestibular function contributed to problems in these areas.

Subjects

Forty stroke patients were selected using relevant inclusion/exclusion criteria, from a larger population undergoing rehabilitation at the Princess Alexandra Hospital in Brisbane.

The criteria used for inclusion of the subjects were that the stroke episode was the first on record for the patient; their age was within 45 and 75 years, an attempt being made to ensure the even distribution of ages; the stroke had occurred within the previous 15 months; and the patients were willing to participate in the study.
Subjects were excluded if a history of cardiac involvement was recorded, severe impairment of visual acuity or problems in judgement of distance with binocular vision was found, and problems of confusion, disorientation or severe receptive aphasia presented. Sixty-five percent of the resulting stroke population were left hemiplegics, the remainder, right hemiplegics. Twenty two subjects, matched for age and sex formed the control group.

**Measurements**

An assessment of the quality of proprioception, body alignment, utilisation of space during movement, verticality perception of the upright as well as an examination of vestibular function, was carried out on all subjects.

Except for vestibular function, separate rating scales, graded to denote increasing severity of the problem, were applied to each of the other assessment areas.

(i) Proprioception

The quality of proprioception was tested by examining joint position sense and passive movement appreciation of the lower limb. The test was performed with the subject blindfolded to eliminate visual cues, and care was taken with placement and pressure of the examiner’s hand to minimise tactile cues.

Each subject was asked to place the unaffected limb in the position that the examiner placed the affected side, and to copy the movement that the examiner was doing with the affected limb to test joint position sense and passive movement appreciation, respectively.

The following rating scale was used to record both responses:

1. Normal, copies positions and movement easily and accurately.
2. Slow, but usually accurate.
3. Wants to check positions and movements visually, but usually accurate.
4. Inaccurate representation of limb position and movement.
5. Grossly inaccurate, no idea of position or movement, does not attempt the tests.

(ii) Body Alignment

The quality of body symmetry was determined by the subject’s ability to align the body to the upright in both sitting and standing. For accuracy, the patient was seated or stood against a background of wire meshing from which a plumbline was hung. The subject was asked to sit and stand as straight as possible (verbal cueing), and, after measurement of the angle between the plumbline and the centre of the body, alignment was recorded according to the following rating scale:

1. Normal symmetrical pattern of alignment.
2. Alignment fair, between 1° and 5° from the midline.
3. Alignment poor, being greater than 5° from the midline.

Because conditions of poor illumination may cause deterioration in body alignment after stroke, testing was carried out in conditions of normal illumination. A comparison of measurements under both conditions would be of interest in a future study.

(iii) Utilisation of space during movement

The quality of body movement in space was also recorded in both sitting and standing. Patients were asked to transfer weight from their unaffected to their affected side and, if required, were given assistance to complete the test. The rating scale used to record this quality was:

1. Normal, moves confidently into left and right space.
2. Tends to avoid movement toward the affected side (left or right), but will do so confidently with assistance.
3. Lacks confidence to move beyond the midline toward the affected side without assistance.
4. Fear of falling, even if assisted with movement towards the midline when moving towards the affected side.
5. Fearful when stationary.

(iv) Verticality Perception

For the purpose of identifying the problem of verticality perception, the quality of accuracy of the upright was selected for testing in this study. An effort was made to control the variables that have been identified in the literature as contributing to errors in verticality perception. (Witkin and Asch, 1948; Werner and Wagner, 1952; Bauermeister, 1964; Bauermeister et al., 1964; Weintraub, 1964; and O’Connell et al., 1967).

It has been shown by Birch et al. (1961) that errors in judgement of the vertical after stroke are more inferior to normal subjects when testing is conducted in dark conditions. For this reason testing in this study was conducted under conditions of normal illumination and with the room darkened to remove visual cues during testing.

The apparatus used consisted of a box containing a light source. The box had a rotatable front segment with a narrow six inch long slit in it which enabled the light to be
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presented as a vertical shaft or at any angle between 0° and 180° by manual rotation.

Twelve trials were conducted with each subject. In all cases, the subject was seated in the upright position, eight feet from the apparatus. The light shaft was rotated from the left for three trials and from the right for a further three trials. This procedure was repeated with the room darkened although the light was turned on between each trial to minimise adaption to conditions of poor illumination. The light shaft was rotated from below the horizontal to the point where the patient perceived it to be upright. Following measurement of the angle of perception of the upright, an average of the scores gained in light, then dark conditions, formed the basis for rating the quality of verticality perception as:

1. Accurate (within 1° of the upright position).
2. Slight problem (1° to 5° from the midline).
3. Mark problem ( >5° from the upright position).

The results gained from the test of verticality perception were used as the basis for grouping the stroke population into two experimental groups. Those 'stroke' subjects with verticality perception problems were grouped together as experimental group 1 while the remaining 'stroke' subjects were placed in experimental group 2(v).

Examination of Vestibular Function

As the measurement of rotational induced nystagmus provides greatest selectivity and objectivity in the assessment of vestibular function, it was selected as the method of choice in this study.

A motorised Barany type chair was used to induce the nystagmus response, which was recorded on an electronystagmography.

The chair was run by a motor which provided for rotation to either the right or left at a rate of one revolution in two seconds. According to Monnier, (1970), this rate is the standard for testing vestibular function.

The location of the controls in relation to the chair and platform was designed for convenient operation and enabled both the ENG machine and the rotation of the chair to be managed by the one examiner.

A vertically adjustable head piece attached to the back support controlled the head position of all subjects at a suitable height during the rotation tests, as well as at 30° of flexion, the

optimal position for stimulating the horizontal semicircular canals (Monnier, 1970). A second attachment supported the electrode leads above the subject’s head.

The Rotation Test

Prior to each rotation test, the patient was positioned directly in front of the control box and the nature of the test, as well as the likely physiological reactions that frequently accompany rotational experiences, were described. Throughout the experiments, an assistant provided reassurance for the patient and recorded the pulse rate, respiration and the reaction of the patient to rotation in order to avoid overstimulation.

Three rotation tests were performed: the first test was always to the subject’s right side with eyes open and was used to give the subject an opportunity to experience rotation, and later a means of comparing the response to the rotation test to the right without vision. To enable the full sensitivity of the vestibular system to be measured, visual fixation was removed by blindfolding the patient in the second and third tests, which were to the left and right respectively. Following cessation of rotation, the patient was encouraged to keep the blindfold in place until the nystagmus reaction observed by the examiner, appeared to stop.

Each test was conducted at ten minute intervals and consisted of five revolutions at a rate of one revolution in two seconds. Monnier (1970) reports that the nystagmus response gained from 10 revolutions in 20 seconds is usually 30 to 40 seconds in duration if visual fixation is removed, and 10 to 15 seconds if visual fixation occurs. However, in consideration of the age of the population studied and as a control group of non-brain damaged subjects provided for comparison of responses, fewer turns were given.

Parameters Recorded

In each rotation test, the post-rotational nystagmus response was recorded. Although three parameters can be examined from the ENG recordings, (duration of nystagmus, amplitude of beats, and frequency of beats), the duration of post-rotational nystagmus was the parameter chosen for comparison purposes in this study.

Researchers working with children have demonstrated that two measurements of post-rotational nystagmus duration can be determined, (Ornitz et al. 1974). These are termed uninterrupted and interrupted post-rotational nystagmus duration. The uninterrupted response is defined as occurring when there has been no activity on the ENG tracing for one second, even though the interrupted or total duration may be longer.

The uninterrupted response provides for ease of objectivity in analysis of the post-rotational

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duration, and as such, this value as well as the total duration studied, is used in comparison with other modalities tested. In an attempt to be more objective in judgement of the cessation of total duration, the ENG tracing was compared to spontaneous ocular activity before rotation.

RESULTS

Following collation of results for each area assessed, comparison of performance by the three subject groups was made.

A comparison of the performance in verticality perception, proprioception, body alignment, and utilisation of space during movement is illustrated in Table 1.

For subjects in the control group no abnormalities in these qualities were demonstrated. However, marked differences were revealed in the responses of the two experimental groups for each of these parameters.

As subjects had been grouped according to the quality of verticality perception (Table 1:A), in both light and dark conditions, it was only in experimental group 1 that the problem was determined. It can be seen from this table that 42% of this group perceived the upright within the defined normal of 1° in light conditions, although a further 42% and 16% of subjects had mild and severe problems respectively when tested in light conditions.

**TABLE 1**

<table>
<thead>
<tr>
<th>ASSESSMENT AREA</th>
<th>SUBJECT GROUP</th>
<th>(Percentage of Subjects)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Experimental Group 1, n = 26</td>
<td>Experimental Group 2, n = 14</td>
</tr>
<tr>
<td>A. Verticality Perception</td>
<td>Light</td>
<td>Dark</td>
</tr>
<tr>
<td>1</td>
<td>42</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>42</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>50</td>
</tr>
<tr>
<td>B. Proprioception</td>
<td>Lower Limb</td>
<td>Lower Limb</td>
</tr>
<tr>
<td>1</td>
<td>11</td>
<td>57</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>35</td>
<td>22</td>
</tr>
<tr>
<td>5</td>
<td>19</td>
<td>7</td>
</tr>
<tr>
<td>C. Body Alignment</td>
<td>Sit</td>
<td>Stand</td>
</tr>
<tr>
<td>1</td>
<td>65</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>57</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>31</td>
</tr>
<tr>
<td>D. Use of Space During Movement</td>
<td>Sit</td>
<td>Stand</td>
</tr>
<tr>
<td>1</td>
<td>31</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>61</td>
<td>31</td>
</tr>
<tr>
<td>3</td>
<td>8</td>
<td>23</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>38</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

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conditions. However, it was when testing was conducted in dark conditions that all subjects with the problem were determined, and 50% of subjects were shown to each have mild or severe problems respectively.

This finding suggests the need to utilise dark conditions, or a suitable method of eliminating environmental cues, to determine the full extent of the problem of verticality perception in the stroke population.

With regard to the quality of proprioception (Table 1:B), marked differences were revealed between the two experimental groups while all subjects in the control group had efficient perception of this modality.

The subjects in experimental group 2 (those with normal verticality perception), were found to have normal proprioception, or problems of a mild nature, in 71% of cases studied. In contrast, only 46% of experimental group 1 (those with problems in verticality perception), had this quality of proprioception.

More severe problems in the quality of proprioception, such as inaccurate judgement or loss of proprioception, were found in both groups. However, while only 29% of experimental group 2 subjects had these more severe problems, a larger proportion of experimental group 1 subjects (54%), were found to be inaccurate in judgement, or have no idea of position or movement sense when tested.

The way in which the quality of proprioception influences verticality perception, posture and may become clear in the analysis of results.

Tests of body alignment (Table 1:C) also demonstrated interesting comparisons between the subject groups. In sitting 93% of experimental group 2 exhibited symmetry of posture and only 7% presented with mild asymmetry of posture. In contrast, 65% of experimental group 1 presented with efficient posture while the remainder demonstrated a mild problem in alignment. Posture was less efficient in standing for both groups, but particularly in experimental group 1. In the latter group, only 8% exhibited symmetry of position while 57% of experimental group 2 retained efficient posture in standing. Problems of alignment in standing were determined in 88% of subjects in experimental group 1 (31% being severe), and in 43% of experimental group 2, of which 7% were severe. These results reinforce the need to determine the cause of poor body alignment.

Examination of the tests involving utilisation of space during movement (Table 1:D), reveals that there is also a notable difference between the performance of the experimental groups in both sitting and standing tests. Experimental group 2 subjects (those without verticality perception problems), demonstrated quite efficient movement, particularly in sitting. Even in standing, 50% of this group retained efficient movement, moving into right and left space confidently during weight transference from the unaffected to the affected side. In contrast, only 31% of experimental group 1 subjects had efficient movement in sitting while in standing only 4% retained efficiency of movement during weight transference.

Mild problems in using space during movement were demonstrated in 69% of experimental group 1 subjects (those with verticality perception problems), compared to 7% of experimental group 2 subjects. In standing, 54% of experimental group 1 subjects and 43% of experimental group 2 subjects had a tendency to avoid movement to the affected side. More severe movement problems were only revealed in standing, for 38% of experimental group 1 subjects, compared to 7% of experimental group 2 subjects with such patients being fearful of falling even if assisted with movement towards the midline.

These findings also reinforce the need to determine the cause of problems in movement efficiency.

For the rotation tests, although a distribution of scores for each subject group existed, results have been presented according to the average reading determined for each group. The average of the uninterrupted and the interrupted (total) post-rotational nystagmus duration scores is illustrated in Table 2.

With regard to the average of the uninterrupted scores gained, differences were revealed between the control group and the experimental groups, although when visual fixation was allowed, a difference between the two experimental groups also became apparent. Following the test of rotation to the right with eyes open average scores of 10, 14 and 24 seconds were achieved by the control group, experimental group 2 and experimental group 1, respectively. This suggests that even when visual fixation is allowed, those subjects with verticality perception problems tend to have more prolonged reactions to rotation. Examination of the results of the tests involving rotation to the right and left with eyes closed, reveals that the response in both directions is similar in each group, but more elevated for the stroke population.

When the averages of the interrupted (total) duration scores are compared, the difference between the experimental groups became even more apparent, particularly for those tests which eliminated visual fixation. It can be seen in Table 2, that the response of those stroke subjects without verticality perception problems experimental group 2 are similar to those gained in the control group. Experimental group 1 subjects (those with
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TABLE 2
COMPARISON OF PERFORMANCE IN AVERAGE DURATION OF POST-ROTATIONAL NYSTAGMUS BETWEEN EACH EXPERIMENTAL GROUP

<table>
<thead>
<tr>
<th></th>
<th>Average Duration Post-Rotational Nystagmus (Secs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rotation (R) Eyes Open</td>
</tr>
<tr>
<td></td>
<td>A   B   C</td>
</tr>
<tr>
<td>Uninterrupted</td>
<td>24  14  10</td>
</tr>
<tr>
<td>Interrupted</td>
<td>39  25  20</td>
</tr>
</tbody>
</table>

A: Experimental Group 1 (n = 26)
B: Experimental Group 2 (n = 14)
C: Control Group (n = 22)

vertically perception problems), achieved an average score that was more prolonged in duration after rotation, particularly when vision was occluded.

These findings suggest that subjects within experimental group 1 (i.e. those with verticity perception problems) are more sensitive to motion as revealed by their prolonged duration of nyustagmus following rotation. The results also suggest that use of the total duration reading more readily demonstrates the difference between stroke patients with and without verticity perception problems. Testing under blindfold, or by reducing visual fixation, demonstrates the full extent of the increased sensitivity of subjects with verticity perception problems, although in this study, the increased sensitivity of this group to motion is also demonstrated when visual fixation is permitted. The relationship of vestibular function to verticity perception, posture and movement may become apparent in the analysis of results.

ANALYSIS AND DISCUSSION

The relationship between each parameter tested was determined by performing linear regression analyses for relevant sets of results. As expected there were no significant correlations between any of the parameters tested for the control group, nor when verticity perception was analysed for experimental group 2 subjects. However, a number of significant findings were determined for both experimental groups in the analyses of results.

The quality of verticity perception was found to influence body alignment in both sitting and standing, and in most instances, influenced the quality of utilisation of space during movement, particularly in standing (see Table 3:A). The demonstration of this significant influence of verticity perception on posture and movement is of considerable importance to physiotherapists in their management of the stroke patient. It has become evident that testing for problems in verticity perception is necessary, as is directing treatment towards the cause of this problem, to enable re-education of posture and movement efficiency after stroke.

Analyses involving proprioception demonstrated quite a variable influence of this parameter on the qualities correlated. For those subjects with problems in the quality of verticity perception (see Table 3:B), proprioception was found to significantly influence this parameter but only when testing was conducted in conditions of normal illumination. Results gained when testing of verticity perception was conducted in dark conditions were not significant and in contrast to findings from earlier studies. The size of the population studied may explain these findings and there is a need for further study in this area.

A significant relationship was found to exist between proprioception, posture and movement in standing, but only for those stroke subjects without verticity perception problems (Table 4). The findings that proprioception influenced posture and movement only in standing was expected as only the results of testing proprioception in the lower limbs were used in the analyses. However, it would appear that the posture and movement of subjects with verticity perception problems is more influenced by their verticity perception problem, than by their quality of proprioception which was earlier demonstrated as being quite deficient in a large proportion of this group. It may be that when verticity perception is not a
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THE RELATIONSHIP OF VERTICALITY PERCEPTION TO POSTURE, MOVEMENT AND PROPRIOCEPTION FOR EXPERIMENTAL GROUP 1.

A. POSTURE AND MOVEMENT

<table>
<thead>
<tr>
<th>Body Alignment</th>
<th>CORRELATION WITH VERTICALITY PERCEPTION</th>
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<tbody>
<tr>
<td></td>
<td>Light Conditions</td>
</tr>
<tr>
<td>Sitting</td>
<td>.521</td>
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<tr>
<td>Standing</td>
<td>.407</td>
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</tbody>
</table>

Use of Space During Movement

<table>
<thead>
<tr>
<th>Use of Space During Movement</th>
<th>Corr. Coeff.*</th>
<th>Signf. Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting</td>
<td>.507</td>
<td>.01</td>
</tr>
<tr>
<td>Standing</td>
<td>.591</td>
<td>.001</td>
</tr>
</tbody>
</table>

B. PROPRIOCEPTION

<table>
<thead>
<tr>
<th>Corr. Coeff.*</th>
<th>Signf. Level</th>
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<tbody>
<tr>
<td>.357</td>
<td>.10</td>
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</tbody>
</table>

* Figures presented represent the Pearson 'r' Correlation Co-efficient (Corr. Coeff.) for each pair of parameters analysed.

Although results from all rotation tests correlated significantly with verticality perception in experimental group 1, the most significant findings occurred for tests involving rotation to the left. It is likely that this result was influenced by the relatively high percentage of left hemiplegics (61.5%) in the study. For the correlations involving posture and movement efficiency, significant findings were mainly found with tests involving eye closure, which supports the need for testing vestibular function with eyes closed. Finally, although vestibular function correlated significantly with all parameters, results were of greatest significance when verticality perception was tested in a dark room, and when body alignment and utilisation of space during movement were tested in standing.

THE RELATIONSHIP BETWEEN PROPRIOCEPTION, POSTURE AND MOVEMENT FOR STROKE SUBJECTS WITHOUT PROBLEMS IN VERTICALITY PERCEPTION

<table>
<thead>
<tr>
<th>POSTURE AND MOVEMENT</th>
<th>CORRELATION WITH PROPRIOCEPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject in Standing</td>
<td>Corr. Coeff.*</td>
</tr>
<tr>
<td>Body Alignment</td>
<td>.515</td>
</tr>
<tr>
<td>Use of Space during movement</td>
<td>.451</td>
</tr>
</tbody>
</table>

* Figures presented represent the Pearson 'r' Correlation Co-efficient (Corr. Coeff.) for each pair of parameters analysed.

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The relationship between the interrupted (total) duration of nystagmus, verticality perception, posture and movement

**TABLE 5**

<table>
<thead>
<tr>
<th>Verticality Perception: Conditions</th>
<th>Rotation (R) Eyes Open</th>
<th>Rotation (R) Eyes Closed</th>
<th>Rotation (L) Eyes Closed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>.334</td>
<td>.10</td>
<td>.333</td>
</tr>
<tr>
<td>Dark</td>
<td>.351</td>
<td>.10</td>
<td>.349</td>
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<tr>
<td>Body Alignment</td>
<td></td>
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<tr>
<td>Sitting</td>
<td>.120</td>
<td>Not Sig.</td>
<td>.435</td>
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<tr>
<td>Standing</td>
<td>.158</td>
<td>Not Sig.</td>
<td>.444</td>
</tr>
<tr>
<td>Use of Space During Movement</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>.023</td>
<td>Not Sig.</td>
<td>.521</td>
</tr>
<tr>
<td>Standing</td>
<td>.341</td>
<td>.01</td>
<td>.519</td>
</tr>
</tbody>
</table>

* Figures presented represent the Pearson 'r' Correlation Co-efficient (Corr. Coeff.) for each pair of parameters tested.

Conclusions

The results of this study demonstrate the need to include an assessment of the qualities of proprioception, vestibular function and verticality perception as a routine procedure in all neurological examinations of the stroke patient so that their influence on posture and movement efficiency can be determined.

It has been shown that testing for verticality perception should be conducted in dark conditions, or by a method that eliminates environmental cues, to enable all patients with the problem to be identified. With regard to testing of vestibular function by recording rotation induced nystagmus, testing for the full sensitivity of the system is best done under blindfold, although the subjects with verticality perception problems did demonstrate a more prolonged duration of nystagmus even with eyes open. However, as the most significant findings were expected following the results presented earlier. It can be seen that the quality of vestibular function can contribute to the problems found in verticality perception, posture and movement after stroke and that effective management of the stroke patient needs to consider vestibular dysfunction if these problems are to be optimally resolved.

The data illustrated in Table 6 also demonstrates that even in the absence of verticality perception problems (as in those correlations involving experimental group 2), vestibular function was found to influence the quality of posture and movement in space. However, such findings were only significant when the uninterrupted post-rotational nystagmus duration readings were used which supports the value of using both readings in the study. The correlations involving vestibular function from the three rotation tests were most significant when compared to the quality of body alignment in sitting, and when compared to the quality of utilization in space in both sitting and standing. Such findings suggest the need to examine vestibular function carefully following all stroke episodes, and not only in those cases with problems in verticality perception.

While it has been shown that the use of both...
VERTICALITY PERCEPTION

TABLE 6
THE RELATIONSHIP BETWEEN THE UNINTERRUPTED DURATION OF NYSTAGMUS, POSTURE AND MOVEMENT FOR STROKE SUBJECTS WITHOUT PROBLEMS IN VERTICALITY PERCEPTION

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Sitting</td>
<td>0.685</td>
<td>0.01</td>
<td></td>
<td>0.620</td>
<td>0.02</td>
<td></td>
<td>0.656</td>
<td>0.01</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Sitting</td>
<td>0.685</td>
<td>0.01</td>
<td></td>
<td>0.620</td>
<td>0.02</td>
<td></td>
<td>0.656</td>
<td>0.01</td>
<td></td>
</tr>
<tr>
<td>Standing</td>
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<td>0.001</td>
<td></td>
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<td>0.05</td>
<td></td>
<td>0.376</td>
<td>Not Sig.</td>
<td></td>
</tr>
</tbody>
</table>

* Figures presented represent the Pearson 'r' Correlation Co-efficient (Corr. Coeff.) for each pair of parameters tested.

uninterrupted and interrupted post-rotational nystagmus duration scores has value in examination of vestibular function for the stroke patient in this project, there is a need for further study of these parameters with a larger population. This study pointed to the need for accuracy in judgement influence of vestibular function on verticality perception, posture and movement, was realised from those tests involving eye closure, testing in the clinical setting should consider methods for minimising the effect of visual fixation. Such a procedure is particularly important if there is no apparent dysfunction when testing allows visual fixation to occur. The value of using 20 Diopter lenses could be considered if access to electro-nystagmography is unavailable.

Examination of these qualities would enable early identification of the influence of verticality on posture and movement as well as a determination of those factors which contribute to dysfunction in verticality perception, posture and movement. This study has demonstrated that the quality of proprioceptive and vestibular function are at least two of the factors which could be contributing to dysfunction in these areas. With regard to demonstrating the involvement of the vestibular system to these problems, it would appear that use of the total duration reading would be most appropriate at this stage when subjects have verticality perception problems, although it has also been shown that the uninterrupted scores correlate with posture and movement in those stroke patients without verticality perception problems. It is obvious that continued study in this area is necessary to determine more clearly the relevant use of both measurements.

Following early identification of the parameters contributing to problems of verticality perception, posture and movement, more effective management of these areas could be initiated. The use of proprioceptive and vestibular stimulation techniques is indicated for the management of the problems identified in this study.

Attention to the causes of poor verticality perception in particular, may help to minimise the failure of patients to achieve ambulation, who have severe problems in this area.

ACKNOWLEDGEMENTS

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BIBLIOGRAPHY

LOW CHOY


VERTICALITY PERCEPTION


