Master Thesis

The influence of sitting position on (ventro-) dorsal head translation

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1. Abstract

Acceleration/deceleration injury of the cervical spine goes ahead with translatoric head movements in the first phase of the trauma. Different tilts in sitting position may influence the amount of head translation movement and therefore the vulnerability of cervicooccipital structures. In the present experiment the degree of “passive” head translation was investigated in upright and in 15 ° tilted chair position.

The pure translatoric head movement was achieved by a helmet fixed on a pole. Co-movement of the thoracic spine was suppressed by pressing a plate against the spinous process of C7. The so measured degree of translatoric mobility was compared with the cervical spine motility in yaw and pitch, with a forearm-elbow-test and with the fingertip-to-ground-test.

The different chair position (upright, 15° tilted backwards) did not have a systematic influence on the translatoric head movement. Possibly this can be explained by the fact that a chair tilted backwards only 15° does not change the position of the cervical spine to a great extent.

Comparing the translatoric head movement with the motility of the cervical spine and the forearm-flexion-test it could be shown that in subjects with hypermotility the degree of translatoric head movement decreased. One can suppose that the test movement is not only a passive one but that it activates an inhibitory mechanism which decreases the amount of translatoric head movement especially in subjects with hypermotility.

A further finding was that during repeated head movements the amount of translatoric head movement decreased continuously. This fact can be interpreted as an increasing inhibition, too.

Keywords: Human – ventro-dorsal head translation – hypermotility - whiplash injury

2. Introduction

2.1. **Generell few**

Day by day lots of motor vehicle accidents happen, annually a third of them are rear-end impacts. In rear-end impacts the head is subject to high rotational and translational acceleration forces. Those accidents are responsible for 85% of injuries classified as „whiplash“ (Osterbauer, 1992). The term whiplash has been applied to the mechanism of injury, to the injury resulting from this mechanism and to the syndrome of neck pain. The definition of whiplash injury remains controversial and this is the reason why it is not yet a legitimate diagnosis for the damaged cervical spine.
Experimental studies (Severy et al. 1955; Clemens and Burow 1972) and computer models (McKenzie and Williams 1971; White and Panjabi 1978) have clearly defined the sequence of events following a rear-end collision (Barnsley et al. 1994): at the time of impact, the vehicle is accelerated forward, followed after 100 ms by a similar acceleration of the patient’s trunk and shoulders induced by the car seat. The head with no force acting upon it remains static in space, resulting in forced extension of the neck as the shoulders travel anteriorly under the head. Following extension, the inertia of the head is overcome, and it is also accelerated forward. The neck then acts as a lever to increase the forward acceleration of the head and force the neck into flexion (Gay and Abbott 1953).

Forced flexion applies compressive forces to the anterior elements and tensile forces to the posterior elements of the cervical spine. The structures resisting flexion anteriorly are the intervertebral discs and vertebral bodies, whereas the posterior structures stretched by flexion are the zygapophysial joint capsules, articular pillars, ligamentum nuchae and posterior neck muscles. Flexion at the atlanto-axial joint will stress the alar ligament complex as the atlas attempts to rotate anteriorly over the axis.
Forced extension of the cervical spine applies compressive forces to posterior structures and tensile forces to the anterior structures. The anterior structures principally at risk are the oesophagus, anterior longitudinal ligament, anterior cervical muscles, odontoid process and the intervertebral discs. The posterior structures at risk are the spinous process and the zygapophysial joints. Although the exact center of rotation for each individual segment

during forced extension is not known, almost any shift away from the physiological axis will result in the zygapophysial joints being the first site of bone-to-bone contact during extension, and hence the fulcrum for further rotation.

Throughout the cervical spine lateral flexion of a given segment is strictly coupled to rotation of that segment, and the degree of coupling is determined by the orientation of the cervical zygapophysial joints (Penning 1991). If an external force laterally flexes the neck, the structures at risk of injury will be determined by the extent to which coupling occurs. If the force simply reproduces physiological movements, the zygapophysial joint capsules on both sides and the intervertebral discs will be most at risk from axial torque, whereas, if there is little coupling, lateral flexion will compress the ipsilateral zygapophysial joint and distract the contralateral joint.

In sitting position in a motor vehicle, the long axis of the cervical spine is approximately vertical. Typically, motor vehicle accidents produce horizontal forces so that most shear will be perpendicular to the long axis of the neck. Movements produced by shearing forces in this setting are small excursion and are less likely to affect muscles which are vertically orientated, elastic structures. Rear impact will have less effect on the zygapophysial joint surfaces but will tense the joint capsules and stress the anterior part of the disc (Barnsley et al. 1994)

In summary, during motor vehicle accidents the neck is subject to forced flexion, extension and lateral flexion as well as shear forces parallel to the direction of impact. These movements are unlikely to occur around physiological axes (Lysell 1972; Frankel 1976; Penning 1991) as the muscles that normally help control the direction and amplitude of motion, do not have time to respond to the forces applied to them (Foust et al. 1973; Schneider et al. 1975).

In the first phase high acceleration forces on the cervical spine initiate a dorsal horizontal translation movement of the head in relation to the accelerated body. Little is known about the contribution of this hypertranslation to the early stage of whiplash injury. It could be essential for the biomechanics of whiplash injuries and could be responsible for its posttraumatic symptoms (Penning 1992).

Based upon a review of the literature, Penning (1994) supposed dorsal hypertranslation of the head, not hyperretroflexion, to be the primary pathogenic mechanism of whiplash injury. This horizontal translation movement of the head backwards in relation to the accelerated body would cause an overstretching of the ligaments and the joint capsules of the atlanto-axial segment. It would lead to chronic ligamentous instability of the upper cervical spine and a compensating hypertensity of the muscles in this area, too.

The disorder of the proprioceptive information concerning the position of the head relative to the body with chronic disturbances of posture and equilibrium is explained by thus generated chronic ligamentous instability of the upper cervical spine (Penning 1992)

2.2. **Objectives**

In humans the contribution of this early hypertranslation to the clinical picture of whiplash injuries is not yet sufficiently explained by experimental results. Nothing is known about the influence of sitting position and seat ranking on ventro-dorsal head translation. Regarding the increasing number of car accidents, it is worthwhile to decrease the risk of neck injury by optimizing the car seat design. The most important design parameters are a low horizontal distance between head and head restraint height (Steffan et. al. 1995). But most head restraints in cars are constructed to prevent only hyperretroflexion. A distance of some centimeters between head and head restraint is too large to avoid hypertranslation during the first 2 or 3 tenth of a second. Besides there are types of cars in which the driver is sitting strictly upright, in others more sportive ones the seat is tilted and the head of the driver is pitched forward.

Assuming that the amount of hypertranslation in the very early phase of impact could depend on head-to-trunk position in pitch axis and that large translation amplitude would enlarge the risk of injury, it would be of interest to optimize the seat ranking. Therefore the aim of this study is to investigate the influence of sitting position on the amount of ventro-dorsal head translation in subjects which are sitting in a chair upright or in a chair tilted 15° backwards.

The hypothesis to be tested predicts a decrease in dorsal head translation while sitting in a chair tilted backwards.

The relevance of the tests for osteopathy could be found in the classification of injured people and their motility in the range of ventro-dorsal head translation after accidents. The knowledge about their behavior could affect the methods of treatment.

3. Background

In order to understand the long-lasting complaints after whiplash injury much more should be known about biomechanics of the cervical spine and its ligaments, intervertebral discs and facets: the human cervical spine has seven vertebrae (C1-C7) stacked one above the other with the intervertebral discs in between at each level except between C1 and C2. The relative motion between the vertebrae is controlled by the muscles but governed by the ligaments, facets and the discs. The biomechanically relevant anatomy is discussed in detail by White and Panjabi (1978).

The supraspinous ligament originates in the ligamentum nuchae which is a firm fibrous band extending along the midsagittal plane from the greater occipital protuberance to the seventh cervical posterior spinous process. The supraspinous ligament continues along the tips of the spinous process as a round, slender strand down to the sacrum.

The interspinous ligaments connect adjacent spines and their attachments extend from the root to the apex of each process. The two ligaments (supraspin. and interspin.) are relatively incomplete in the upper cervical spine but are better and more consistently developed in the lower cervical spine.

The ligamenta flava are broad, relatively elastic ligaments extending from the posterior inferior border of the laminae above to the posterior superior border of the laminae below. They connect adjacent laminae from the second cervical to the first sacral vertebrae.

The capsular ligaments are short but thick and join the adjacent inferior articular process of the vertebral level above and the superior articular process of the level below.

The facet joints are covered with a thin layer of cartilage and are oriented anteriorly and posteriorly at about 45° angle relative to the longitudinal axis of the cervical spine.

The amount and type of movement that occurs in the vertebral column is determined by the discs, ligaments and, to a significant extent, by the shape and orientation of the articular facets.

In the cervical region, these structures are arranged in a way that most of the axial rotation (50°) of the head on the neck occurs between the atlas (C1) and the axis (C2). Flexion and extension also occur at this joint but lateral bending is negligible.

In the lower cervical spine (C2-C7) flexion, extension and lateral bending motions are extensive. The axial rotation between individual pairs of vertebrae (motion segments) is slight in comparison to the upper thoracic region. Lateral flexion is always coupled with a certain amount of axial rotation. This coupling is such that during lateral bending to the left the spinous processes go to the right and vice versa (Goel and Goyal, 1984).

The degree of atlanto-axial rotation is estimated by the anatomists (Fick 1904, 1911) to be about 30° to either side. According to the classic anatomic textbooks the center of atlanto-axial rotation is located in the center of the odontoid process (Fick 1904, 1911).

This is in accordance with observations that the center of the odontoid process in the rotated position is found halfway between the lateral masses of the atlas. It remains in contact with the anterior arch of the atlas which is also the case in the non-rotated position of the normal cervical spine.

The same is true for the lower cervical spine; mean rotation in the cadaver experiments of Lysell is about 75% of that in Penning's study. In accordance with the findings of Lysell is Penning's observation that rotational mobility is greatest in the segments between C3 and C6 and least at C7-T1. Likewise, in accordance with the findings of Lysell is the large individual variation in range and distribution of rotational mobility of the lower cervical spine.

It is known that rotation in the lower cervical spine is, of necessity, combined with lateral flexion to the same side, creating a concavity of the lower cervical spine to the side of rotation. In the lower cervical spine the axis of rotation runs more or less perpendicular to the intervertebral joint plane (Penning 1987).

The role of the muscles in providing clinical stability to the spine is secondary to that of the ligaments in normal physiological situations. Although it has not been proven, however, it is supported by the observations of Perry and Nickel (1959). It is the posterior elements that provide the stability in flexion and the anterior elements in extension. Mechanics of the motion segments of the spine is greatly affected by the facet orientations. Application of horizontal force in the sagittal plane, produces not only horizontal displacement, but also rotation. This phenomenon of coupling was more dominant in flexion than in extension (Panjabi et al 1975).

4. Material and Methods

The device to measure head translation was optimized in a previous study investigating the influence of head rotation on dorsal head translation. The extent of translation was measured in twelve subjects at three different head positions: neutral, rotated to the right and to the left. Most of the subjects showed a decrease of the extent of translation during head rotation (Marchhart 1998).

4.1. **Material**

In the above mentioned pretests the variability of data was found to be small, therefore a sample of twenty healthy volunteers was considered to be sufficient. 10 males and 10 females without any history of cervical spine injuries, took part in this investigation (males aged 36.85 +/- 4,1; females aged 36,38 +/- 4,1).

4.2. **Apparatus**

In my study the subject was placed into a special chair, head upright, the back in touch with the back of the chair, the feet were flat on the floor and the legs uncrossed (**Fig 1 a**). The tilted chair position was achieved by a wooden wedge (**Fig 1 b**).
To prevent co-movements lower than the cervical spine, the spinous process of vertebrae of C7 was fixed from behind (**Fig 1 c**). The subject was wearing a helmet. This helmet was connected with a pole which allowed forward-backward translation movements but suppressed rotation, flexion and extension (**Fig 1 d**).

The amount of translation of the head was registered by an incremental angle decoder. A chin-holder was fixed at the frame of the helmet. The force applied by the examiner in ventro-dorsal direction was measured by a grip with a force transducer which was pressed against the chin-holder (**Fig 1 e)**. The measured force was monitored on a screen.
Pretests were carried out to improve the experimental device and to optimize the test procedure. It was essential to train the experimenter to apply constant force on the chin-holder during dorsal moving of the chin.
Those pretests brought about first results to estimate the amount of variability between subjects. It was tested for learning effects and for trends in time within repeated measurements.

4.3. **Procedure**

After the subjects were informed verbally, they signed an informed consent. The test motions were explained to them.
The subject was seated up straight in the chair, the feet were flat on the floor and the legs uncrossed. The hands were placed on the thighs. The back was leant against the back restraint. Head position was defined by visual fixation of a target in the horizontal line of the eyes (target-eye-distance 2 meters). In the so defined position a plate was fixed from behind against the spinous process of vertebrae of C7 and the helmet as well as the chin-holder was set.
Performing tests in upright chair position the examiner passively moved the subject’s head slowly ventro-dorsal up to the limit of the passive movement. The force applied was kept constantly by visual control of force amplitude. The subject was instructed to admit the passive head movement by following the ventro-dorsal pressure against the chin.
To get used to this procedure, three test movements were done without recording.
After each translation movement, the subject was asked to fix the visual target and to position the head in neutral. By doing so a randomly varied starting position for the next translation movement was available.

4.4. **Experimental design**

Each subject was examined in a test (set 1, set 2) and in a retest an hour later (set 3, set 4), always by the same examiner. The device was always applied according to a standard procedure and the setting kept constantly in each subject in spite of the breaks.

Test:

In chair upright condition (set 1) five test movements (= 5 trials = run 1) were performed in the above described manner. After a 30 s break, the same procedure was repeated (= 5 trials = run 2; run 1 and run 2 = set 1).

After a 10 min break the chair was tilted. In this chair tilted condition again two times 5 trials were performed (2 runs = set 2)

Retest:

After one hour the procedure described above was repeated, starting with chair tilted condition (set 3) followed by chair upright condition (set 4).

In between test and retest additional motility tests were carried out. The other time the subjects were allowed to walk around or sit.

Additional Motility tests:

To get an external criterion to classify subjects, the amount of head motion (range of movement) in two axis (yaw and pitch) was assessed using Cervicomotography. This method allows six-dimensional kinematic analyses of active and passive head movements (**Fig 2 a, b)** (Berger 1990, Berger et al. 1998).

The degree of overall motility was estimated in each subject by two tests. The first test investigated the distance fingertips to ground during forward bending of the trunk (FBA-test; Kapandji, cit. Sachse 1992).

The second test measured the extension movement of the articulatio humero radialis/ulnaris angle, forearms together (forearm-flexion-test = Elbow-Test).

Both tests classified motility in three qualities: hypomotility/normal; hypermotility; distinct hypermotility.

4.5. **Analyses**

The raw data were brought into Excel-Tables and mean and standard deviation were calculated for translation amplitudes and force amplitudes.

The steps of further data analyses were:

- Frequency distributions of the translation amplitudes
- Testing for significant difference in means and standard deviations of translation and force amplitudes
- Individual differences
- Comparing test-retest-results (reliability of measurements)
- Influence of personal variables as age, gender, degree of motility, ROM of head
- Relationship of translation amplitude and ROM in yaw and pitch

5. Results

5.1. **Testing for homogeneity of samples**

Inspection of the measurements showed that in all experimental sets the first of the five trials was different to the four others **(Fig. 3)**. A closer look revealed that the force amplitudes concerning the first translation movements were significantly smaller **(Fig. 4)**. Therefore the first trial of each run was excluded from further analyses.

Fig. 5 shows the frequency distribution of the translation amplitudes of both chair conditions. The values are ranked from 1,3 cm to 6,4 cm with a maximum of 3,1 cm. A second peak is seen with higher amplitudes of 7,8 cm. Those data stem from one subject (No.15). The investigation of test- and retest distributions of translation amplitudes **(Fig. 6)** shows that the high amplitudes of Subject No.15 have not been reproduced in retest.

Therefore subject No.15 was excluded from the sample and further analyses of data were done with a more homogeneous sample.

5.2. **Testing for significant difference in means and standard deviations of translation amplitudes:**

The mean translation amplitudes of the two chair conditions did not differ significantly. The difference of the translation amplitudes is smaller than 3 mm **(Fig. 7)**

Chair	**Test**	**Mean Ampl.**	**Stand. Dev.**	**Stand. Error**	**N**
0°	1	3,58 cm	1,12	0,18	152
0°	2	3,13 cm	0,92	0,15	151
15°	1	3,24 cm	1,08	0,17	152
15°	2	3,34 cm	0,98	0,16	152

Table 1: Mean translation amplitudes of the two chair conditions; Graph Table 1 see Appendix

Comparing test and retest, the differences of translation amplitudes between upright and tilted chair positions are only significant for test-condition, it could not be reproduced in retest **(Fig. 8)**

5.3. **Testing for individual differences in translation amplitudes**

Fig. 9 represents the translation amplitudes for 19 subjects and the two chair conditions. The subjects are ranked according to gender (1-10 =females; 11-19= males) and degree of motility (smaller to higher = from the left to the right in each gender). Some of the subjects show a marked influence of seat position, but investigating test and retest, only one subject (No. 17) shows a reproducible effect **(Fig. 10and Fig. 11)** .

5.4. **Testing for time-dependent changes in translation amplitudes**

In the course of the Test there is a tendency to decreasing translation amplitudes, an effect which can be shown in Retest, too **(Fig.12)**

5.5. **Testing for Reliability (Differences in translation amplitudes in Test and Retest)**

Time-dependent changes in translation amplitudes within one run resp. one set as well as between test and retest suggest that reliability cannot be guaranteed. Repeating translation movements brought about an aftereffect which changes the outcome **(Fig.13).**

5.6. **Testing for an influence of force amplitude on translation amplitude**

Regarding mean force amplitudes the request to keep the applied force constant, was followed within limits of 15,1 and 16,1 Newton (**Fig.14)**. In two subjects the force was little higher (subject No.11) respectively smaller (subject No.13) **(Fig. 15).**
Surprisingly, the relation between amount of force and translation amplitude was inverse: the higher the applied force, the smaller the translation amplitude **(Fig. 16).**

5.7. **Testing the influence of individual variables**

5.7.1.Gender:

There was not any significant difference between males and females concerning translation amplitudes in test and retest **(Fig. 17).**

5.7.2.Age:

Regarding subjects aged from 31 to 43, there is a slight tendency to decreasing translation amplitudes with increasing age **(Fig.18).** Subject No.13 shows maximum translation amplitudes in spite of minimal acting force (compare Fig. 15)

5.7.3.Motility

5.7.3.1. Distance fingertips to ground during forward bending of the trunk (FBA-Test) **(Fig. 19)**

There is a tendency to a positive correlation: an increase of translation amplitudes is seen in cases with increasing motility (from hypomotility/normal to hypermotility)

5.7.3.2. Forearm-flexion-test (Elbow-Test) **(Fig. 20)**

Translation amplitudes are significantly increased in subjects grouped in “hypermotility”. Subjects in group “distinct hypermotility” show very small translation amplitudes**.** This phenomenon is seen in **Fig.21**, too. In subjects the coincidence of ranking in FBA-Test (“hypermotility” and “distinct hypermotility”) and ranking in Elbow-Test (“hypermotility”) generates high translation amplitudes. If the motility in the elbow test is estimated higher (“distinct hypermotility”), the translation amplitudes are reduced dramatically.

5.8. Testing for a relation of translation amplitude and range of movement (ROM) in yaw (axial head rotation) and pitch (flexion/extension)

5.8.1. Passive and active ROM in yaw:

19 subjects were ranked according to increasing ROM. A positive correlation is only seen in ROM smaller 150°/160° (**Fig. 22, Fig. 23**)

5.8.2. Passive and active ROM in pitch:

As seen in **Fig 24** and **Fig. 25**, there is a positive correlation of ROM and translation amplitude except in subjects with maximum ROM in active head movements. There the translation amplitudes are markedly decreased.

6. Discussion

6.1. The influence of sitting position on ventro-dorsal head translation

Concerning the results of this study, the hypothesis that predicts a decrease in dorsal head translation while sitting in a chair tilted backwards 15°, has to be refused. A chair tilt of 15° backwards does not influence the amount of ventro-dorsal head translation in a systematic manner.

Possibly this can be explained by the fact that a chair tilted backwards only 15° does not change the position of the cervical spine to a great extent. Maybe that a larger tilt of the chair, that is an increased flexion of head-to-trunk, would have shown the expected effect. But the amount of chair tilt was chosen to simulate seat rankings in cars. In most cars the head-to-trunk-tilt is not larger than 15° because the horizon as the reference axis must be seen comfortably.

6.2. **The influence of different degrees of cervical spine motility on ventro-dorsal head translation**

Our hypothesis was that hypermotility of the cervical spine in yaw and pitch would correlate with increased ventro-dorsal translation amplitude. This was only true for subjects with small and medium range of head movement in yaw (active and passive). The cases with maximum range of head movement showed an unexpected decrease in translation amplitude.

How to explain this phenomenon?

By asking the subjects for their feeling during the "passive" ventro-dorsal head translation they reported increasing tension of the cervicooccipital region. This feeling could be explained by the biomechanics of this movement: Concerning the results of Penning's x-ray-studies the translation movement is done by flexion of the upper cervical spine and retroflexion of the lower cervical spine. In everyday condition the flexion of the cervical spine is part of forward-bending of the head. This forward-bending is possible due to a decreased tension and elongation of dorsal muscles. But the tested movement is not a physiological one because the head is fixed in upright position and the helmet prevents the forward bending of the head. Therefore the ventro-dorsal pressure resp. ventro-dorsal translation may cause an increased tension of dorsal muscles due to a protective inhibitory mechanism. One has to take into account the vulnerability of structures of this region, that are cervicooccipital ligaments and muscles, dura, spinal cord, radices etc. especially in a translatoric movement. Increased tension of dorsal muscles inhibits a flexion of the upper cervical spine and therefore decreases the ventro-dorsal translation amplitude. It seems to be reasonable that in cases of hypermotility of the cervical spine this protective inhibitory mechanism seems to be pronounced.

6.3. **Overall motility and ventro-dorsal head translation**

Subjects with high ratings in forearm-flexion-test show the same pattern as in cervical spine motility test: that is, hypermotility goes together with a marked decrease of translation amplitude.

In the fingertip-to-ground-test this relationship was not seen. It has to be taken into account that this test is dependent on some variables mainly on the shortening of ischiocrural muscles (ham strings), lumbar muscles and lumbo-dorsal fascia as well as hip motility. It seems that spine motility is not the most important variable in this test. From this point of view it is reasonable that there is no correlation of the fingertip-to-ground-test to ventro-dorsal head translation.

6.4. **Changes in translation amplitude**

It is an interesting phenomenon that in the course of the experiment (set 1 to set 4; Fig. 12) a continuous decrease of translation amplitude could be seen. The effect was independent of chair position. Following the hypothesis mentioned above this could be interpreted as an increase of the above described reflectoric inhibition.

7. Critical view of the method

There are two aspects mentioned concerning the difficulty to develop an apparatus to investigate standardized measurements of the head translation in different position of the body. One of the difficulties in measurements of translation is how to immobilize the upper thoracic spine (co-motion). Upper parts of the thoracic spine, despite fixation of the spinous process of C 7 from behind, may undergo varying degrees of flexion/extension motion during head translation and this will markedly influence the degree of head translation.

Another aspect of translation is vertical displacement of the head (with respect to Th 1). During backward translation the head is displaced in cranial direction. The apparatus does not allow free and unrestricted head movement in vertical direction.

8. Conclusion

Based on the results one can conclude that the described translation test does not prove the passive mobility in a ventro-dorsal direction. It seems to be that the “passive” translatoric head movement in the test procedure is not a real passive one but a highly controlled active task. As soon as the cervical spine has got a postural function for holding the head in an upright position, muscular activity is needed. Only in supine position of the body and stable support of the head one can expect a minimum of muscular activity of the cervical spine. To answer primary questions of the present study, it is planned to compare x-ray-investigations in upright position and in supine positions.
A further interesting finding was that the kind and intensity of muscular activity during these test movements seems to depend on the degree of motility resp. hypermotililty. At the time not much is known about the individual strategies and behavior of hypermobile individuals. This is a large field for further research.

The complex symptoms of patients suffering from whiplash injury are particularly suitable for osteopathic treatment due to its holistic perspective of the human being.
Because of the dorsal horizontal translation movement of the head in relation to the accelerated body is supposed to be the primary pathogenic mechanism of whiplash injury this study is a contribution to basic medical research. As these results indicate only for hypermobile humans the sitting position in the car is of importance. Nevertheless, no conclusion could be given to different methods of treatment for different motility ranges within the cervical spine of humans. This study is located in the field of basic medical research and could be helpful in the osteopathic treatment as preventively advice. The further interesting finding about the behavior of hypermobile individuals could be a suggestion for further research activities, especially in the theory of protective inhibitory mechanism.

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10. Legends

Fig. 1 a: Subject in upright chair position

Fig. 1 b: Subject sitting in the chair tilted backwards 15°

Fig. 1 c: Subject wearing the helmet. The spinous process of vertebrae of C7 was fixed from behind

Fig. 1 d: Device to measure head translation: helmet connected with a pole which allows forward-backward translation movements suppressing rotation, flexion and extension

Fig. 1 e: Examiner pressing the chin-holder with the force transducer grip slowly into ventro-dorsal direction

Fig. 2 a, b: Cervicomotography, which measures the range of passive and active head movements in yaw and pitch

Fig. 3: Translation Amplitude [cm] dependent on sequence number in set (1 set = 2 runs = 10 translation movements), for both chair conditions (chair 0° and 15°), test and retest

Fig. 4: Force Amplitude [N] dependent on sequence number in run (1 run = 5 translation movements)

Fig. 5: Frequency Distribution of translation amplitudes, for both: chair conditions /test and retest

Fig. 6: Frequency Distribution of translation amplitudes, for both chair conditions. Upper graph shows the results of the test, the lower graph the results of the retest

Fig. 7: The influence of chair position (0°, 15° backwards tilt) on translation amplitude [cm] (mean values over test and retest)

Fig. 8: The influence of chair position (0°, 15° backwards tilt) on translation amplitude [cm], separated for test (left graph) and retest (right graph)

Fig. 9: Translation amplitudes [cm] depending on chair position and subject, means over test and retest

Fig. 10: Translation amplitudes [cm] depending on chair position and subject, test only

Fig. 11: Translation amplitudes [cm] depending on chair position and subject, retest only

Fig. 12: Translation amplitudes [cm] depending on sequence number of set (set 1 and set 2 belonging to test, set 3 and set 4 belonging to retest)

Fig. 13: Translation amplitudes [cm] for test and retest and chair upright position (left graph) and chair tilted position (right graph)

Fig. 14: Force Amplitude [N] dependent on chair position

Fig. 15: Force Amplitude [N] depending on subject

Fig. 16: Translation amplitudes [cm] depending on force amplitude [N]

Fig. 17: The influence of gender on translation amplitude [cm], separated for female subjects, chair upright and tilted (left graph) and male subjects, chair upright and tilted (right graph)

Fig. 18: Translation amplitudes [cm] depending on age (years)

Table 1: Mean translation amplitudes of the two chair conditions

Table 2 : Variation of individual variables in subjects: gender, age, degrees of motility in distance fingertips-to-ground-test (FBA), forearm-flexion-test (Elbow) and range of passive and active head movements in yaw and pitch

Graph 1: Mean translation amplitudes of the two chair conditions (Appendix)

Appendix

Curriculum

Geboren 20.11.1962 in Zams, Tirol

1969 –1973 Volksschule in Innsbruck

1973 –1977 Hauptschule in Innsbruck

1977 – 1981 Bundesoberstufen-Realgymnasium Innsbruck

1981 –1982 Heeresdienst

1982 –1985 Physiotherapieausbildung Akademie

Berufstätig als Physiotherapeut:

1985 –1988 Universitätsklinik für Chirurgie, Innsbruck

1988 –1991 Leitung der Physiotherapeutischen Abteilung Krankenhaus Bludenz

1991 –1992 Sportphysiotherapie Innsbruck

ab 1992 Physiotherapeut Neuroorthopädische Ambulanz, Universitätsklinik für Neurologie, Innsbruck

1994 – 2000 Osteopathie-Ausbildung Wien

As a physical therapist at the Neuroorthopadical Department of the University Hospital of Neurology in Innsbruck I mainly attend patients after whiplash injury. Three years ago I worked on a clinical study which compared the kinematics of head movement disturbances in patients with neck pain after whiplash injury and healthy subjects which tried to simulate painful head movements.

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