

Intra and intermuscular control of hemiplegic patients and its alteration due to vibration exposure

Thesis

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INTRODUCTION

With the increasing age the incidence of brain damage is gradually increasing in the World and consequently in Hungary, too. Among the neurological diseases the cerebrovascular accident is in the first place. The increasing number of the cerebrovascular disease and survivors, the pressure on the societies has increased not only in curing, but in development of life quality of these patients as well. Probably this was one of the reasons which motivated the researchers to deal with this problem and to discover the causes of cerebrovascular diseases, and use the results in rehabilitation of these patients.

One of the areas of the researches has been muscle contractility of the intact and the affected side and the intra-muscular control of the muscles. The other major research area has been the study of inter-muscular coordination during multi-joint movement and the motor control under altered circumstances. Numerous studies dealt with the analysis of gait and standing stability. New rehabilitation tools and methods are the interest of the researchers.

Despite of the intense researches on the disease of central nervous system which accelerated during the past 20-30 years, there are several essential problems which still wait for solution. Understanding the essence of these problems new rehabilitation methods can be developed.

We have been motivated to start researches on stroke patients and hemiplegic people to discover new data and to augment our knowledge concerning voluntary muscle contraction and neuromuscular coordination of these patients.

Concerning rehabilitation of patients with stroke and with other cerebrovascular accident we interested in testing a new device and methods on stroke patients, which was already proved on healthy people and athletes. Namely, we wanted to test the effect of whole body vibration on muscle strength of stroke patients.

AIM OF THE RESEARCH

Study 1

The aim of the study was to determine different contractility variables of the knee extensors in both the intact (IS) and affected side (ES) during isometric (IC), concentric (CC) and eccentric (EC) contractions applying unilateral (UL) and bilateral (BL) knee extensions for young chronic hemiplegics (YCH).

Study 2

The aim of this experiment was to determine the selected variables of isometric and eccentric contractions for IS and ES in elderly acute stroke patients (EAS) during UL and BL.

Study 3

The aim of the experiment was to study the motor control of elderly patients with mild stroke during target oriented arm movement.

Study 4

The aim of the experiment was to study the effect of one session whole body vibration (WBV) on the mechanical variables of the knee extensor muscle on the effected side under isometric and eccentric contractions.

Study 5

The aim of this study was to investigate the effect of four week WBV on contractility variables of knee extensor of intact and effected side under isometric and eccentric contraction. Subjects recruited in study 4 were tested in this study.

METHODS

Study 1

Measurement of the mechanical variables was carried out by using a computer aided dynamometer (Multicont II) in sitting position. Isometric torque was tested at knee angle positions of 30, 60 and 90 degrees. Five constant angular velocities (0.52, 1.04, 2.09, 4.18, 5.2 rad/s) were applied for estimation the characteristics of concentric contraction. The knee extension started at 90° and terminated at 10°. In eccentric contraction three constant velocities ((0.52, 1.04, 2.09 rad/s) was used between 30 and 50 degrees, and between 60 and 80 degrees.

Study 2

Isometric torque was measured at a joint angle of 60°. Eccentric contraction was carried out with 1.08 rad/s constant velocity between 30 and 90 degrees of knee angle.

Study 3

Ten healthy people (HP) and ten stroke patients (SP) participated in this study. Subjects were instructed to extend the arm from a fixed starting position into a straight forward position. The task was to repeatedly put the hand as precisely as possible in the same location in space. The subjects repeated the movement 30 times with eyes open and 30 times with eyes closed. The movement was recorded by an ultrasound based motion analyser system (Zebris). We determined the „x” and „y” coordinates of the hand at the end position. Also, seven joint angles of the shoulder, elbow and hand was determined at the end position. Variance analysis was used to determine the variability and degree of freedom of the final hand and arm position, and the arm trajectory as well

Study 4

Sixteen elderly patients with acute stroke were recruited and randomly assigned for vibration (VG) and control (CG) group. VG received five times one minute vertical vibration with one minute rest between applying 20 Hz resonance frequency with 0.5 cm amplitude. Subjects stood on a Nemes vibration plate flexing the knee 40 degrees during vibration exposure. Knee extension was tested before treatment and after treatment within 10 minutes on Multicont dynamometer applying similar measurement procedure as described in study 1 and 2. Myoelectrical activity of m. vastus lateralis (VL) and m. biceps femoris (BF) was recorded using a Noraxon telemetric device. Root mean squared EMG (rmsEMG) and median frequency (MF) was determined and co-activation quotient was calculated.

Study 5

WBV was applied during four weeks, three times per week. The vibration occurred similarly as in study four except the resonance frequency was increased from 20 Hz to 25 Hz in the third and fourth week. The vibration exposure was also increased week by week from 5 times one minute to 11 times one minute vibration. Same mechanical variables were determined as in study 4 one day before WBV treatment and after three days having finished the treatment.

RESULTS

Study 1

Isometric contraction. Maximum isometric torque (Mic) at ES was significantly less than at IS. The percentile difference ranged between 25.4 % and 44.7 %. The smallest difference was found at 60° and the greatest at 30°. The difference between the two sides in Mic was similar applying UL or BL. The rate of torque development during contraction (dM/dt), RTDc) and rate of torque development during relaxation (RTDr) was less in ES than in IS. However, significant difference was observed only at 60° in RTDc and 30° in RTDr. The bilateral deficit (BLD) ranged between 71.4 and 88.6 % in the function of joint angles.

Concentric contraction. Peak torque was significantly less for ES than for IS at each velocity applied in UL. When calculating average torque the difference between IS and ES was significant only at 0,52, 1,04 rad/s. In BL the difference between the two sides was only significant at the lowest two velocities in both peak and average torque. Considering mechanical work (W) the difference between IS and ES was significant at 0,52, 1,04 rad/s in UL. In BL the difference in W was significant at each velocity except at 5.2 rad/s.

Eccentric contraction. The torque (Mec) and mechanical work (Wec) was always depressed in ES as compared with IS. In UL, considering peak torque (Mec) significant difference was found between IS and ES at all velocities applied at 60-80 degrees. In average

torque there was only significant difference with 0.52 rad/s at 30-50 degrees and with 2.09 rad/s at 60-80 degrees. Concerning Wec the difference between the two groups was significant with 0.52 and 1.08 rad/s at 30-50 degrees, and with 2.09 rad/s at 60-80 degrees. In BL the differences between the two sides were almost the same as in UL. Difference between UL and BL was found only with the greatest velocity applied at the intact side, mostly. The BLD values in % was the lowest at 2.09 rad/s for all variables. The Mec/Mic ratio was similar a sin healthy people (1.12-1.54). The ratio was significantly greater in BL than in UL.

Study 2

Isometric contraction. Mic was 43.5 or 50.1 % less in ES than in IS during UL or BL, respectively. Similar significant differences were observed for RTDc and RTDr. The BLD was 79.3 %.

Eccentric contraction. Mec was 50.1 % less for ES than for IS during UL and 42.3 % less during BL. In both conditions the differences has been significant. The BLD was 79.3 %. The patients were able to produce 2.3 or 3.1 times greater mechanical work with their intact knee extensor than with effected muscle during UL or BL, respectively. A BLD was 90.3 %. The Mic/Mec ratio ranged between 1.47 and 1.87 which are greater than those reported for healthy people. The ratio remained unchanged during BL for ES, but increased significantly for IS.

Comparison of YCH and EAS groups.

Isometric contraction. YCH were able to produce significantly greater Mic than EAS with both IS and ES. The difference between the two groups was greater in the effected side. RTDc was almost twice greater in YCH compared with EAS. The difference was greater at ES than at IS. Also the difference between the two groups was greater during BL. There was even greater difference between the two groups in RTDr.

Eccentric contraction. Peak torque was significantly greater for YCH than for EAS at the effected side, but no significant difference was observed at the intact side in either UL or BL. The Mec/Mic ratio was greater in EAS than in YCH at UL, but no significant difference was observed at BL.

Study 3

The variability of hand positioning was significantly greater in SP than in HP without visual control. No difference was found between the two groups with visual control. Contrary,

the degree of freedom of the arm at the final position was significantly lower for SP than for HP with eyes open. No difference was found at eyes closed situation.

The variability of the final arm position influenced the final hand position with 50 % only. In this respect there was no significant difference between HP and SP groups.

Concerning a given initial and final hand position the variability of trajectory of the arm was similar in HP and SP. Also, there was no significant difference observed between the two groups in coordination of joints and in execution time

Study 4

Mic was 26.6 % greater after treatment in VG and no alteration was observed in CG. RTDc was elevated after WBV in both groups (VG: 12.3 %; CG: 12.6), but the difference was not significant in either groups.

Mec increased significantly (15.6 %) in VG, but it remained unchanged in CG. Mechanical work was 14.3 % elevated in VG after WBV that is significant change. No change was observed in CG.

The rmsEMG of VL was significantly greater with 36.5 % after WBV in VG under maximum isometric knee extension. The rmsEMG activity of BF did not change. No significant alteration was found during torque development (RTDc) either in VL or in BF.

The rmsEMG was greater with 25.6 % in VL and less with 18.6 % in BF after WBV under eccentric contraction. There was no change in rmsEMG in CG. MF was greater with 11.5 and 7.9 % at isometric and at eccentric contraction, respectively in VG. The co-activation quotient significantly increased with 60.0 % at isometric knee extension in VG.

Study 5

Significant changes due to WBV was observed in VG, only.

Isometric contraction. Mic was significantly greater in ES than in IS after WBV at both UL (45.2 % elevation) and BL (45.6 % elevation). There was also elevated Mic in IS, but significantly less than in ES (UL: 13.1%; BL:20.8%). RTDc was also greater after WBV at both IS and ES during UL and BL. BLD was greater with 3.1 %, but the change has not been significant.

Eccentric contraction. Mec in ES was greater with 26.3 % and 31.9 % after WBV at UL and BL, respectively. In IS although Mec increased, but the change was not significant. BLD remained unchanged. Mechanical work was greater after WBV in ES only (UL: 31.7 %; BL: 40.8 % elevation). Mec/Mic ratio has not changed significantly.

EMG activity. The rmsEMG activity of VL muscle was greater after WBV at both UL and BL, but only in ES. The significant change was observed under isometric and eccentric contraction as well. The EMG activity of BF was greater after WBV under isometric contraction only in ES. Co-activation quotient was significantly depressed at isometric and eccentric contractions, but only in EF.

CONCLUSION

Muscle contractility

Young chronic hemiplegic patients

- The result of this study suggests that the average torque during bilateral isometric contraction is a more valid variable to determine the contractility deficit than the peak torque.
- It seems that the bilateral knee extension has facilitation on the effected muscle during concentric contraction carried out with high velocity.
- The results may allow us to conclude that when the muscles contract under eccentric contraction applying bilateral contraction, expedient to use low stretching velocity. Higher torque production can be attained during unilateral eccentric contraction if the stretching velocity is higher.
- Muscles in the effected side have been more sensitive for the stretching velocity than the muscles in the intact side.

Elderly acute stroke patients

- The maximum isometric torque of knee extensors on the effected and intact side has been a good indicator to show the degree of impairment, and it showed the low level of regeneration of the patients despite the early start of rehabilitation.
- It seems that the significant difference between the two side in RTDc is not the consequence of the muscle atrophy and spasm only, but deficit of the neural control plays a significant role in it, too.
- Presumably, the increased torque due to muscle stretch can be attributed not only to the stretch of the elastic elements, but also to the stretch reflex which might result in an increase of firing rate of the recruited motor units and/or recruitment of new motor units.
- The bilateral torque exertion did not result in selective respond in the effected side in contrast to young hemiplegics, which can be attributed to the impairment in communication between the two hemispheres.

- The results allow us to conclude that mechanical work during eccentric contraction is a better indicator of muscle function than the peak torque. It seems that Mec/Mic ratio is a more complex parameter to estimate the level of impairment of the motor cortex and degree of improvement than the isometric and/or eccentric torque.
- The bilateral deficit is not influenced by the duration of regeneration and age.

The control of arm movement

- The results suggest that the precise execution of motor task causes problems for patients with mild stroke rather than the execution of the motor task.
- The visual feedback almost perfectly compensates the deficiency of movement execution due to the weakness of muscle strength or movement coordination.
- Despite the imprecise hand positioning the patients are able to solve the redundancy problem. Namely, the patient were able to reduce the degree of freedom of the arm movement.

Whole body vibration

Acute residual effect

- One set (5 times 1 minute vibration exposure) of whole body vibration (20 Hz frequency, 5 mm amplitude) transiently increase the isometric and eccentric strength of knee extensors on the effected side.
- Most probably the strength enhancement was induced by the residual acut effect of tonic vibration reflex.
- The enhanced transient strength may help to improve the effectiveness of rehabilitation in standing stability and gait.

Chronic effect

- Four week whole body vibration resulted in significant increase in strength of knee extensors during isometric and eccentric contraction which can be attributed to the neural adaptation, because the EMG activity of m. vastus lateralis increased significantly.
- The the ratio of EMG activity of vastus lateralis and biceps femoris contributed to the enhanced torque generation after vibration treatment.
- The bilateral deficit decreased under isometric contraction only due to vibration. We may conclude that the vibration might stimulate the motor cortex, because the isometric force production depends upon the voluntary effort predominantly.

- The effect of vibration was observed mostly in the effected side. The reason of this finding can be attributed to the applied resonance frequency domain. Namely, the frequency of 20-25 Hz has not provided enough stimuli for the intact side.

Own publications

The theses based on the following publications

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11. Horváth M, Fazekas G, **Tihanyi T**, Tihanyi J. (2005) Standing stability of hemiparetic patients estimated in different ways. *Facta Universitatis*, 3:59-58.
12. Tihanyi J, Bogner P, **Tihanyi T**, Gyulai G, Vácz M. (2002) Morphological properties and specific tension of the quadriceps femoris muscle. *Hungarian Review of Sport Science*, Special Issue 2002 pp. 4-10.
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