EXPERIMENTAL INVESTIGATIONS

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Effect of Visual Feedback Information on Isometric Contraction of Forearm Flexor Muscles in Men and Women After Ischemic Stroke

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Key Words: *ischemic stroke; isometric contraction; accuracy; visual feedback.*

Summary. *The aim of this study was to determine the effect of visual feedback information (VFI) on the isometric contraction of the forearm flexor muscles in men and women after an ischemic stroke when doing a physical load at 20% of strength.*

Material and Methods. The study included healthy subjects (n=20) and subjects after ischemic stroke (n=20). The study was conducted in Lithuanian Sports University. The measurements of maximum voluntary strength (MVS) and accurate isometric contraction were performed using an isokinetic dynamometer Biodex System Pro 3.

Results. The absolute errors of isometric contraction of the right arm muscles at 20% of MVS were similar in all the groups during the attempt with visual feedback information. The smallest absolute errors of the healthy subjects were 1.42±0.35 Nm when the task was performed with visual feedback and the greatest absolute errors were 4.69±0.95 Nm (P<0.01) while performing the task without visual feedback. Meanwhile, the smallest and greatest absolute errors of the subjects after ischemic stroke were 1.32±0.45 Nm and 5.05±0.63 Nm, respectively, while performing the task without visual feedback (P<0.01).

Conclusions. Maximum voluntary strength was greater in all the groups of men. The absolute errors of isometric contractions of the right and left arm muscles tended to increase in both the men and the women when there was no visual feedback information. The women and the men after an ischemic stroke produced greater absolute errors when performing the task with the right and left arm without visual feedback information than the healthy subjects.

Introduction

Stroke is one of the most frequent diseases and the third most common cause of death and disability over the world. Patients after stroke most often have weakened control of movements, which results in limited mobility (1). Stroke mostly affects muscles of one arm and leg and one side of the face (about 80% of patients) since their function largely depends on the motor cortex (1–3). After stroke, patients have worse control not only of the affected limb, but also movements of the opposite limb (3).

Stroke affects the muscle strength of the upper limbs more than that of the lower limbs. Distal muscles weaken more compare to proximal, and forearm extensors are more affected than flexors. Meanwhile, knee flexors are more affected compare with knee extensors after stroke (3, 4).

It has been known that the atrophy of fast-twitch muscle fibers is noticeable whereas slow-twitch muscle fibers are hypertrophied after stroke. Thus, normal voluntary contraction and motor control are impaired (5).

Visual feedback is extremely important when performing movements, especially the new ones, and an appropriate choice of this feedback can facilitate learning of those movements, because the movement can be controlled observing its trajectory (6, 7). Visual feedback information can be provided orally (when the information about the result or the performance of the movement itself is said) and visually (when the performance of the action is shown on screen, watching the video, or demonstrating on the other person) (7–9). The feedback can be obtained from many sources: brain, muscles, tendons, skin, eyes, etc. (7, 8). When the task has to be performed without visual feedback information, the motor program controlling the movement performance and regulating the feeling of the movement plays a major role (7) since sensory noise, which influences the accuracy of the movement, appears when the feedback sources, e.g., sight, decrease (10).

A number of studies have shown that older people make errors when trying to perform the movements

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as accurately as possible without feedback information in comparison with young patients (11, 12), and it is not clear what errors are made by people after stroke. Movements are slower and more inaccurate in patients after stroke compare with healthy subjects (9). Thus, movement speed and accuracy are affected, but it is questionable if errors are made while developing required muscle strength.

It is possible to develop the voluntary isometric contraction of the muscles of arms and legs more accurately when the curve of the muscle strength is seen (13, 14). It remains unclear if visual feedback information may improve the accuracy of isometric muscle contraction after stroke.

We hypothesize that subjects make greater errors without visual feedback information developing 20% of their maximum voluntary strength, and the errors are even greater in the subjects after an ischemic stroke.

Thus, the aim of this study was to determine the effect of visual feedback information on the isometric contraction of forearm flexor muscles in men and women after an ischemic stroke when doing a physical load at 20% of strength.

Material and Methods

The study included healthy right-handed subjects (n=20; mean age, 66.05 years; SD, 6.2) and right-handed subjects after an ischemic stroke during their postrehabilitation period (n=20; mean age, 68.6 years; SD, 6.4). All the subjects were divided into 4 groups: 10 healthy women (mean age, 66.2 years; SD, 2.39); 10 healthy men (mean age, 65.9 years; SD, 2.05); 10 women after an ischemic stroke (mean age, 67.2 years; SD, 2.61); and 10 men after an ischemic stroke (mean age, 70.02 years; SD, 1.85).

The inclusion criteria to the study were as follows: middle cerebral artery ischemic stroke, which occurred not earlier than one year, with the left limb hemiparesis, confirmed by medical records; older age (more than 55 years for women and more than 60 years for men); no history of hearing and sight disorders, which could hinder the performance of the tasks, and any other diseases of the central and peripheral nervous system (Parkinson's disease, multiple sclerosis, mental disorders, brain or spinal cord tumors, epilepsy, etc.); no arm joint endoprosthesis; a score of the Mini-Mental State Examination not less than 25; a score of 0 for muscle spasticity according to the Aschwort scale; a score greater than 3 for muscle strength according to Lovett; a score greater than 41 for balance according to the Berg scale; and Barthel index greater than 91.

The permission (No. BE-2-72) for the study was obtained from Kaunas Regional Ethics Committee for Biomedical Research. The subjects were familiarized with the course of the experiment and instructed on how to perform the task correctly 3 days before the experiment. The study was conducted in Lithuanian Sports University (formerly Lithuanian Academy of Physical Education).

Measurement of Maximum Voluntary Strength. An isokinetic dynamometer Biodex System Pro 3 was used in the study. The subjects were seated in a special chair of the dynamometer (at a backrest angle of 90°). During the test, the subject held a special handle with the arm being tested and the belt around the waist with the other arm. Thus, the full amplitude of the elbow joint (with the extended and bent arm) was determined. The tested arm was additionally fixed at the elbow joint and bent at an angle of 60°±5° before that. In order to evaluate maximum voluntary strength (MVS), the subject had to achieve the maximum voluntary strength of muscle contraction. Two attempts were allowed, and the better result was registered.

Accurate Measurement of Isometric Contraction of Forearm Flexor Muscles. The measurement of 20% of MVS was taken for each subject. The subjects had to perform 2 isometric contractions of the forearm flexor muscles with visual feedback information (VFI) and one attempt without it. Every contraction of muscles lasted for 15 seconds with 10-s intervals. In order to obtain accurate results, only the interval of the middle 10 seconds was calculated since other intervals were for the warming of the muscles and possible fatigue. When the subjects had to perform the task with VFI, they saw the line of their 20% of MVS on the screen of the isometric dynamometer, which provided them the information about the performed load (Fig. 1).

In order to evaluate the accuracy of the isometric contraction of the muscle, absolute errors were counted. The absolute errors provided information about how big the mistakes were and showed the accuracy of the isometric contraction (15). They were calculated according to the formula:

$$\text{Absolute error} = \Sigma|x_i - T|/n,$$

where x_i indicates the developed strength (Nm); T, 20% of MVS (Nm); n, the number of attempts;

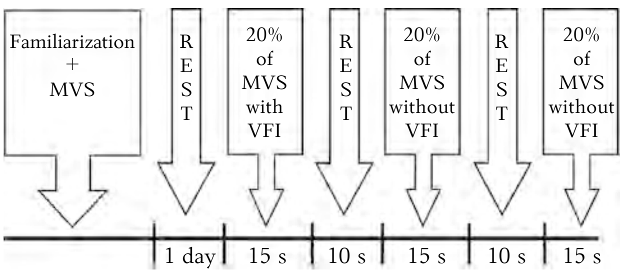

Fig. 1. Research protocol

MVS, maximum voluntary strength;
VFI, visual feedback information.

and vertical brackets (| |) mean that the value was always considered positive.

Absolute errors showed the absolute deviation from the needed contraction strength of the muscle. For example, if the subject needs to exert efforts in order to perform an isometric contraction of the muscles at 20% of MVS, which makes 10 Nm, and he/she performs at 8.5 Nm, the absolute deviation equals 1.5 Nm; if the subject performs at 11 Nm, the absolute deviation equals 1 Nm.

Statistical Analysis. Statistical analysis was performed using statistical packages SPSS for Windows and Microsoft Office Excel 2007. Means of the indices and standard deviation were calculated; confidence interval of the difference between the results according to the Student *t* test criterion of independent variables when doing tasks with the right and left arms and significance of the results of different variables were determined. Statistical significance was set at $P<0.05$.

Results

Before the experiment, MVS of both arms was tested (Fig. 2). Individual 20% of MVS was calculated for all the subjects, and they had to perform tasks according to this value with VFI and without it.

The data of the MVS measurement are presented in Fig. 2. The mean MVS of the healthy women and the women after an ischemic stroke for the right arm was 39.51±8.9 Nm and 27.18±5.3 Nm, respectively ($P<0.01$). Meanwhile, the corresponding values for the left arm were 34.66±9.8 Nm and 26.83±8.8 Nm, respectively ($P<0.05$).

The mean MVS of the healthy men for the right arm was greater than that of the men after stroke (58.24±5.6 Nm vs. 49.13±11.4 Nm, $P<0.05$). Moreover, a significant difference in the mean MVS for the left arm was found when comparing the healthy men and the men after an ischemic stroke (56.48±9.9 Nm vs. 46.53±9 Nm, $P<0.05$).

When 20% of MVS was calculated, it was determined that the healthy women had to exert strength of 7.9±1.8 Nm with the right arm and 6.97±1.9 Nm with the left arm; meanwhile, the women after an ischemic stroke had to exert strength of 5.44±1.1 Nm and 5.36±1.7 Nm, respectively. The healthy men had to exert strength of 11.65±1.1 Nm with the right arm and 11.29±1.9 with the left arm; the men of the target group had to exert strength of 9.83±2.3 Nm with the right arm and 9.31±1.8 Nm with the left arm.

Figs. 3 and 4 the numbers of absolute errors counted after the experiment.

When the healthy women had to perform the task with the right arm with VFI, during the first attempt, they made an error by 1.45±0.55 Nm of strength; meanwhile, the women after stroke, 2.14±0.52 Nm; the healthy men, 2.24±0.54 Nm; and the men after stroke, 2.58±0.85 Nm. Similar results were obtained during the second attempt with VFI: the healthy women made an error by 1.42±0.35 Nm; the women after stroke, 2.01±0.41 Nm; the healthy men, 2.19±0.56 Nm; and the men after stroke, 2.62±0.56 Nm. When the same task was performed with the right arm without VFI, the healthy women made an error by 1.88±0.39 Nm of strength; the women after stroke, 3.51±0.83 Nm ($P<0.05$);

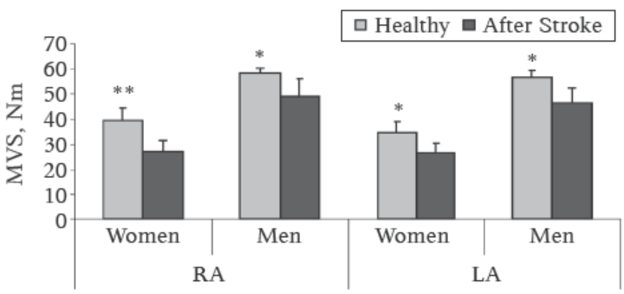

Fig. 2. Maximum voluntary strength of both arms of the subjects

MVS, maximum voluntary strength; RA, right arm; LA, left arm.
$^{*}P<0.05$; $^{**}P<0.01$.

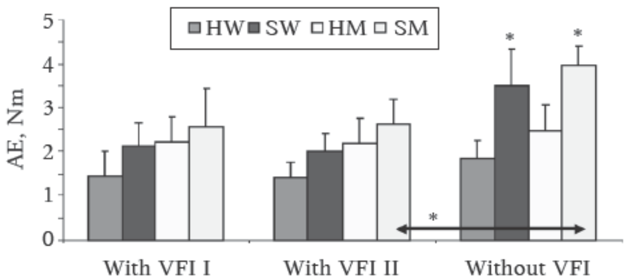

Fig. 3. Absolute errors of the right arm with 20% of maximum voluntary strength

HW, healthy women; SW, women after stroke;
HM, healthy men; SM, men after stroke; AE, absolute errors;
VFI, visual feedback information.
$^{*}P<0.05$.

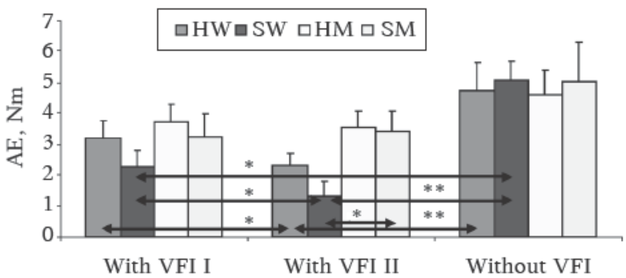

Fig. 4. Absolute errors of the left arm with 20% of maximum voluntary strength

HW, healthy women; SW, women after stroke;
HM, healthy men; SM, men after stroke; AE, absolute errors;
VFI, visual feedback information.
$^{*}P<0.05$; $^{**}P<0.01$.

the healthy men, 2.48±0.57 Nm, and the men after stroke, 3.97±0.45 Nm ($P<0.05$). Significant differences were obtained when comparing the healthy women and the women after stroke without VFI ($P<0.05$), the healthy men and the men after stroke without VFI ($P<0.05$), and the men after stroke with VFI during their second attempt and the men after stroke without VFI ($P<0.05$).

When the subjects had to perform the task with the left arm with VFI during their first attempt, the healthy women made an error by 3.19±0.55 Nm of strength; the women after stroke by 2.28±0.51 Nm; the healthy men by 3.71±0.55 Nm; and the men after stroke, 3.22±0.75 Nm. The results of the second attempt with VFI were the following: the healthy women, 2.32±0.36 Nm of strength; the women after stroke, by 1.32±0.45 Nm; the healthy men, 3.53±0.54 Nm; and the mean after stroke, 3.42±0.67 Nm. When they had to perform the same task with their left arm without VFI, the results were the following: the healthy women made an error by 4.69±0.95 Nm of strength; the women after stroke, 5.05±0.63 Nm; the healthy men, 4.61±0.77 Nm; and the men after stroke, 5.03±1.27 Nm. Significant differences were observed when comparing the first attempt with VFI and the second attempt with VFI in the healthy women and the women after stroke ($P<0.05$), the second attempt with VFI and the attempt without VFI in the healthy women ($P<0.01$); and the first attempt with VFI and the attempt without VFI in the women after stroke ($P<0.05$).

Discussion

The results of our study showed that MVS of both arms in the healthy women was weaker than in the healthy men, and MVS of both arms in the women after an ischemic stroke was weaker than in the healthy women and men after stroke. Meanwhile, MVS of both arms in the men after an ischemic stroke was weaker than in the healthy men, but greater than in the women after an ischemic stroke. Skurvydas claims that the number of motor neurons and their pulsation frequency decrease and intramuscular coordination deteriorates after an ischemic stroke; when normal activation is absent, the muscle atrophies, becomes shortened, generates more connective tissue, and becomes less plastic. These are the major causes for the muscle MVS to decrease after an ischemic stroke (3). Other studies have also reported about a decrease in the muscle mass after an ischemic stroke, especially in the paretic limb. English et al. have studied the strength of paretic limbs and have determined significant differences in the muscle strength between the healthy and impaired arms as well as between the healthy and impaired legs (16).

The results of the first and second attempts with the right arm with VFI were very similar. Without VFI, both the healthy subjects and subjects after an ischemic stroke made greater errors with the right arm. However, the subjects after stroke made significantly greater errors than the healthy subjects and the subjects after stroke with VFI. Both MH and MS made greater errors than the women in both groups when performing the task with VFI. The movement of the right (dominating) arm without VFI increased absolute errors since the neuromuscular system does not obtain information by sight, which helps make movement corrections (10). Arce et al. also suggest that when the movement is performed with external feedback information, the subject can easily control his/her motion observing the movement trajectory; however, with external feedback eliminated, only internal feedback can be trusted (17). According to Cirstea et al., subjects with hemiparesis performed their movements more slowly and less accurately in comparison with healthy subjects, which was also confirmed by our study (9).

The results of the first and the second attempts of the men with the left arm with VFI were very similar, but the women in both groups showed better results, i.e., the errors were smaller during the second attempt. Schaefer et al. reported in their study that the results of subjects after stroke with the right hand were worse than those of healthy subjects when VFI was present; meanwhile, the results in both groups were similar when the same attempt was performed with the left arm. According to the authors, the obtained results showed that the right hemisphere was oriented toward accuracy; thus, the results for the left arm were similar in both the groups (18). Without VFI, absolute errors significantly increased, yet they did not differ significantly in the 4 groups. It is likely that during rehabilitation, greater attention was paid on the paretic limb, which could have influenced the results obtained in the study that absolute errors were similar for the healthy subjects and for the subjects after an ischemic stroke. Besides, Dohle et al. reported that the performance of a movement in front of a mirror (i.e., with VFI) with the healthy arm positively affected the movement control mechanisms of the paretic arm (19).

The subjects could more accurately perform an isometric contraction of muscles while seeing the strength line on the screen. It is thought that the right inferior parietal and anterior cingulated cortices were activated in the presence of feedback, which provided information on how the subjects should correct their performances (20). Therefore, VFI provided a possibility to perform the indicated movement more accurately. Other researchers agree on this and suggest that the learning process gets more complicated without feedback information (7, 21).

Conclusions

Maximum voluntary strength was greater in all the groups of men. The absolute errors of isometric contractions of the right and left arm muscles tended to increase in both men and women when there was no visual feedback information. Women and men after an ischemic stroke produced greater absolute errors when performing the task with the right and left arms without visual feedback information than healthy subjects.

Statement of Conflicts of Interest

The authors state no conflict of interest.

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