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RETENTION OF RELATIVE GRIP EFFORT FOR AT-HOME ISOMETRIC EXERCISE

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ABSTRACT

The purpose of this work was to determine if subjects initially trained to use a handgrip dynamometer could learn to perform the exercises at the same relative level of effort with a considerably less expensive substitute device. All subjects trained (4, 2-minute contractions, 30% maximal effort) 3 times per week for 12 weeks. In Study I, Group 1 (n = 13) trained using only the dynamometer while Group 2 (n = 14) trained using both the dynamometer and an egg-shaped substitute item for the first 6 weeks. All subjects then trained using only the egg-shaped item. Grip effort was evaluated every 2 weeks using the dynamometer. Group 2 subjects gripped at a level consistently closer to the desired level of effort. Study II investigated the importance of the substitute item's shape. Group 3 (n = 10) trained using the egg-shaped item while Group 4 (n = 10) trained using an item that was similar in shape to the dynamometer. Group 4 subjects gripped at a level consistently closer to the desired level of effort. These results suggest that gradual introduction of a substitute item similar in shape to the dynamometer can significantly improve the transfer of handgrip exercise to a less expensive substitute item by increasing retention of desired level of effort.

† † †

Hypertension is a disease characterized by a chronic elevation in blood pressure above 140/90 mm Hg (Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure [JNC] 1993). As many as 50 million American adults (approximately 25% of the adults) have elevated blood pressure or are taking antihypertension medication (JNC 1993). The frequency of hypertension is growing fastest among African-Americans, and the incidence of hypertension is higher among persons who are less educated or who are in lower socioeconomic groups (JNC 1993). Hypertension is also growing among the very old and the very young, as greater than 60% of all American adults age 60 or older have high blood pressure and the incidence of hypertension is increasing among children (JNC 1993). Although the cause of hypertension is unknown in 90% of the cases (Stinson 1988), alterations in neural activity (Esler et al. 1988, Michel et al. 1990), kidney function (Brenner et al. 1988), or insulin sensitivity (Halkin et al. 1988, Tedde et al. 1988) may play important roles in the development of this disease. Untreated hypertension may lead to the development of a number of other disorders, including kidney failure, stroke, and coronary heart disease (JNC 1993). While the number of deaths attributed to hypertension-related diseases has steadily declined as the diagnosis and treatment of patients improves, deaths from various hypertension-related diseases are still 1.5 to 5 fold greater in blacks than whites (JNC 1993).

Treatment for hypertension often involves drug therapy, and the efficacy of such drugs is widely accepted. Patient compliance with drug therapy, however, can be poor since unpleasant side effects of these drugs, including fatigue, headache, palpitations, dizziness, and loss of sexual desire, are not uncommon (JNC 1993). These sides effects, combined with the cost of the medication, may prompt some afflicted persons to discontinue treatment (Cornacchia and Barrett 1993). Various rhythmic (aerobic) exercise programs have also been examined as possible treatments for hypertension. Rhythmic exercise is characterized by a high component of isotonic muscular contractions, that is, muscles go though their range of motion. Examples of rhythmic exercises are walking, bicycling, and swimming, and regular participation in rhythmic exercise is consistently associated with such classic training adaptations as a lower resting heart rate, increased size of the heart, neural and hormonal changes, and weight loss (Cox et al. 1985, Galo et al. 1989, Katona et al. 1982, Ostman and Sjostrand 1971, Schaible and Scheuer 1981, Scheuer and Tipton 1977, Williams et al. 1981). The value of regular rhythmic exercise as a treatment for hypertension, however, is mixed. In some studies rhythmic exercise training has also been associated with a modest reduction in resting blood pressure in individuals with normal resting blood pressure or with mild (borderline) hypertension (Siegal and Blumenthal 1991). In other studies, however, rhythmic exercise training has failed to have any influence on the resting blood pressure of individuals with mild hypertension (Arroll and Beaglehole 1992, Blumenthal et al. 1991). Failure to adhere to an exercise program that involves major life style changes, however, is often cited as a major reason for inadequate control of hypertension through this method of treatment (JNC 1993). Therefore, the long-term effectiveness of rhythmic exercise training as a non-pharmacological treatment for mild hypertension remains unclear.

The potential benefits of isometric exercise training in the reduction of resting blood pressure have long been overlooked. Isometric exercises are those which involve primarily isometric muscular contractions, that is, the muscle develops tension, but no work (or movement) is performed. Exercises such as weight lifting have a high isometric component. More than 25 years ago, it was demonstrated that pure isometric training resulted in lower resting blood pressure in a group of hypertensive individuals (Kiveloff and Huber 1971). In 1985, a study of the incidence of hypertension as related to the occupation of the individual demonstrated a lower incidence of hypertension in individuals whose occupation could be described as having a moderate to high isometric component (Buck and Donner 1985). The implications of these studies were fascinating, but it was not until 1992 that the results of a controlled study investigating the influence of regular isometric exercise on resting blood pressure were published. Wiley et al. (1992) examined subjects with borderline hypertension who used a handgrip dynamometer to perform isometric exercises. Training consisted of timed, repeated efforts at either 30% or 50% of the individual's maximal effort three times weekly for a period of five to eight weeks. Significant decreases in mean systemic blood pressure were observed, and these training effects gradually disappeared within five weeks after the subjects discontinued participation in the training program.

Handgrip dynamometers are relatively expensive devices ($200–$300) and are not commonly available. While a handgrip dynamometer specifically designed for these particular types of isometric exercises has recently been developed (MD Systems, Inc., Westerville, Ohio), it is relatively expensive (over $500) and may not completely meet the needs of all who could benefit from its use. The purpose of this investigation was to determine whether subjects trained in the proper use of the handgrip dynamometer can be trained to perform the isometric exercises at the same intensity on their own using an inexpensive ($10–$15) substitute device. This would enable a patient to learn the technique in a physician's office or laboratory setting and then train at home for several weeks at a time, returning to the office or laboratory only periodically for routine evaluation. Learning to perform the exercises on a substitute item would also be of benefit to those patients who travel frequently as the substitute item would be easier to transport and easier to replace if lost or damaged. It is also believed that the ease and convenience of performing these exercises in the home will increase patient compliance and result in successful, long-term, non-pharmacological treatment of mild hypertension.

MATERIALS AND METHODS

Subjects

Healthy volunteers, ages 18–45, were initially screened by measuring their resting seated blood pressure (BP) three times in a two-week period. During each of the three screening sessions, BP was measured twice from each arm with an aneroid sphygmomanometer and stethoscope using standard auscultatory methods based on criteria recommended by the American Heart Association Postgraduate Education Committee. A total of 12 screening measurements were made. Volunteers whose resting BP averaged less than 140/90 mm Hg were invited to participate in the study. These volunteers received written explanations of the procedures and purposes of the study, and signatures on informed consent documents were obtained from each subject before participation in the study. Subjects were asked to maintain the same exercise, nutritional habits, and general activities during the period of their participation in the study. They were also requested not to change diet, stop or start smoking or consuming alcohol, or initiate other major lifestyle changes. If this was not possible, the subject was to inform the investigators and voluntarily withdraw from the study without prejudice. All protocols were approved prior to the beginning of the study by the Internal Review Board of the University of Nebraska at Kearney and are in accordance with policy statements of the America College of Sports Medicine.

Measurements

Portable Smedley handgrip dynamometers (Flaghouse, Inc., Mt. Vernon, New York) were used to perform the exercises. These dynamometers had been modified in our laboratory slightly from their original form in that a small screw had been inserted so that the tension dial not only measured the maximal effort but also recorded changes in grip strength for an extended contraction. There were two dynamometer sizes available to the subjects. The grip-tension scale of the full-sized dynamometer ranged up to 100 kg (220 lbs) while the grip-tension scale of the scaled-down model ranged up to 50 kg (110 lbs). All subjects were familiarized with the handgrip dynamometer prior to their first training session, designated an exercising arm for the remainder of the study, and performed a maximal effort on the smaller of the two dynamometers. If the subject's maximal effort was greater than the maximal tension recorded by this dynamometer, then the subject used the larger dynamometer for the remainder of the study. The investigators met with each subject at a place convenient to the subject for training sessions. Heart rate (HR) and BP were each measured twice after at least 5 minutes of seated, quiet rest prior to beginning the handgrip exercise. Blood pressure was measured in the non-exercising arm as described above, and HR was measured by palpation of the carotid artery.

For each training session, the subject was first instructed to exert a brief (less than 2 seconds) maximal effort on the dynamometer. After at least 3 minutes of quiet rest, the subject was instructed to perform a second brief maximal effort. If these efforts differed by no more than 5%, the greater tension was taken as the maximum voluntary contraction (MVC) for the day. If a greater than 5% difference occurred, additional grip tensions were measured, with rests between, until a reliable MVC measurement was obtained. Since exercise training could cause MVC to increase, it was necessary to determine MVC at the beginning of each training session.

One minute after completion of resting HR and BP measurements for the day, the subjects began the first of four, 2-minute sustained contractions at 30% MVC. The subject was coached to maintain a steady effort and could continuously view his/her level of effort from a dial on the dynamometer. A rest period of 3 minutes was allowed between each of the successive contractions, all with the same arm. During the last 20 seconds of each contraction BP was measured from the non-exercising arm and HR was measured from the carotid artery . The four HR and BP responses for a given exercise session were averaged and used as an index of the subject's cardiovascular responses to the isometric exercise for that particular training session.

Study I

The purpose of this study was to determine if a gradual introduction to the substitute item would improve the retention of grip effort. A total of 27 subjects completed the study. This group included 6 white males and 21 white females. The average age, height, and weight of the subjects was 25.9 ± 1.6 years, 66.9 ± 0.8 inches, and 150.0 ± 5.1 pounds, respectively (mean ± standard error of the mean). The mean resting BP of the subjects was 115.5/ 71.2 mm Hg ± 2.3/1.7 mm Hg. Prior to the start of any exercise training, subjects were randomly divided into two groups: Group 1 (n = 13) and Group 2 (n = 14). Both groups trained three times a week for a period of six weeks. All training sessions for members of each group throughout the duration of the study consisted of 4, 2-minute contractions at 30% MVC with a 3 minute rest between successive contractions. Group 1 subjects were given no new training information and followed the procedures outlined above using the handgrip dynamometer for the entire six week training duration. Group 2 subjects, however, followed a different training procedure as outlined below. This training procedure was designed to teach these subjects to maintain the desired level of effort without relying on visual information from the tension dial of the dynamometer.

Weeks 1 and 2 - Subjects in Group 2 followed the same training procedures as Group 1.

Weeks 3 and 4 - There were 6 training sessions during this two week period. The goal of these sessions was to gradually wean the subject off his/her dependence on the tension dial to confirm level of effort. During the first two training sessions the subject was allowed to view the tension dial for three of the four contraction efforts, and this decreased to two of four contraction efforts for the middle two training sessions, and then to only one of four contraction efforts for the last two training sessions. The contraction(s) during which the subject was not permitted to view the tension dial during a given training session was randomly determined. During contractions in which the subject was not permitted to view the tension dial he/she was coached to maintain a constant level of effort by an investigator who could see the dial. Heart rate and BP were measured as described previously. The investigator also instructed the subject to be aware of his/her body's response to this effort because each subject had a characteristic response to the exercises. During performance of the exercises both HR and BP increased moderately (for example, one subject consistently had a HR increase of 12 bpm and a BP increase of 20/12 mm Hg over resting values). When the subject performed the exercises without being able to observe the tension dial, the measurement of HR and BP at the end of the contraction was used as an indicator of the subject's level of effort.

Weeks 5 and 6 - During the six training sessions during this two-week period, each subject was gradually weaned away from the handgrip dynamometer to a common non-instrumented hand strength exercising device (The Eggsercizer®, Eggstra Enterprises, Inc., Birmingham, Alabama) that would serve as the substitute item. During this training period subjects performed only one contraction during each exercise session with the handgrip dynamometer when he or she could also view the tension dial, and the placement of the contraction during the training session was randomly determined. During the first two sessions of this training period, the subject performed one contraction using the substitute item, and the placement of this contraction effort was also randomly determined. The number of contractions using the substitute item was increased to two for the middle two training sessions and to three for the final two training sessions. Heart rate and BP were measured as described previously. The subject was instructed to use the same level of effort when exercising with the substitute item, and, when he/she performed the exercise at the appropriate level of effort, the characteristic HR and BP response as noted above was observed.

Following the six-week training period, all subjects in Groups 1 and 2 performed the exercises on their own using the substitute item three times a week for an additional six-week "maintenance" period. This period gave the subjects an opportunity to perform the exercises unsupervised while permitting the investigators to periodically monitor their performance. The subjects were instructed to follow the same procedures used during the training phase, including a maximal effort daily, and to record their training efforts in a training log. Each subject met with an investigator once every two weeks for a training evaluation and check-up. During this evaluation and check-up session, the subject's training log was examined to monitor his or her compliance to the training program, and suggestions were made if the subject had missed exercise sessions or had not spread the training sessions out appropriately during the two week period. All subjects then performed their MVC and first 2-min contraction on the handgrip dynamometer, but none was allowed to view the tension dial. The investigator recorded the actual level of effort (% MVC) on the dynamometer for the first contraction. If the level of effort differed by more than 5% from the desired level of effort (30% MVC), the subject was allowed to view the tension dial for the remaining three contractions in order to confirm the desired level of effort. If the level of effort for the first contraction was within 5% of the desired level of effort, however, the subject performed the remaining three contractions using the substitute item.

Study II

The purpose of this study was to determine if the shape of the substitute has an influence on the retention of grip effort. This investigation was prompted by repeated comments from Study I subjects that the shape of the substitute was so very different from the handgrip dynamometer that it was difficult to judge the level of grip effort. A total of 20 subjects completed the study. This group included 11 white males and 9 white females. The average age, height, and weight of the subjects was 23.1 ± 1.6 years, 66.4 ± 1.7 inches, and 160.0 ± 7.1 pounds, respectively. The mean resting BP of the subjects was 115.1/73.1 mm Hg ± 2.4/1.9 mm Hg. Prior to the start of any exercise training, subjects were randomly divided into two groups: Group 3 (n = 10) and Group 4 (n = 10).

Subjects in groups 3 and 4 followed the same general training regime as Group 2 subjects from Study I. Group 3 subjects also used the egg-shaped substitute item while Group 4 subjects used an adjustable fitness grip (Medical Marketing Consultants, Evanston, Illinois) which more closely resembled the general shape of the hand dynamometer. All measurements were identical to those of Study I.

Statistics

Resting HR and BP before the training period, at the conclusion of the six-week training period, and at the conclusion of the six-week maintenance period were analyzed using a repeated measures ANOVA. Heart rate and BP responses to the isometric exercise effort were analyzed for each of the 18 training sessions also using a repeated measures ANOVA. The percent differences (absolute value) between desired and actual level effort for the first contraction between Group 1 and Group 2 and between Group 3 and Group 4 during the three maintenance period evaluation and check-up sessions were likewise analyzed using a repeated measures ANOVA. Statistical difference was ascribed for $p < 0.05$.

RESULTS

Study I

Subjects in Group 2 were consistently better able to grip at the desired level of effort at each check-up session during the entire six-week maintenance period, and by the third (final) check-up session this difference was significant ($p = 0.0108$). Subjects in this group gripped at a level that differed from the desired level of effort by an average of only 8.9, 10.5, and 6.6%, respectively, during the three check-up sessions, while subjects in Group 1 gripped at a level that differed from the desired level of effort by an average of 17.8, 16.5, and 16.3%, respectively (Table 1).

Resting HR and BP were not significantly changed as a result of the training regime in either Group 1 or Group 2. There were no differences between Group 1 and Group 2 in baseline HR and BP over the six-week supervised training period, nor were there any significant differences in training HR or BP between Group 1 and Group 2 during the six-week supervised training period. Heart rate and BP responses to the exercise

Table 1. Percent difference (absolute value) from desired level of contraction effort for subjects during three check-up sessions within a six-week maintenance period following six weeks of isometric exercise training using a handgrip dynamometer. Subjects in Group 2 (n = 14) were gradually introduced to a substitute exercise item prior to the maintenance period while subjects in Group 1 (n = 13) were presented with the substitute item for the first time at the beginning of the maintenance period. All subjects used only the substitute item during the maintenance period. Check-up sessions were scheduled approximately every two weeks during the maintenance period. Values expressed as mean ± standard error of the mean.

Study Group	Check-up #1	Check-up #2	Check-up #3
1	17.8 ± 6.1	16.5 ± 4.8	16.3 ± 3.1
2	8.9 ± 3.7	10.5 ± 3.3	6.6 ± 1.8 *

*Significantly different from Group 1, $p = 0.0108$.

effort were unchanged within Group 1 and Group 2 during the six-week training period. During the six-week maintenance period following the supervised training period, resting HR and BP remained unchanged from initial resting levels in both Group 1 and Group 2, and there were no differences in resting HR and BP between Group 1 and Group 2.

At-home training logs were collected from all subjects at the conclusion of the study. All subjects reported completing 15 training sessions on their own. In addition, all subjects met with the investigators 3 times (once every 2 weeks).

Study II

Subjects in the Group 4 were consistently better in gripping at the desired grip strength at each check-up session during the entire six-week maintenance period, and by the third (final) check-up session this difference was significant ($p = 0.0047$). Subjects in Group 4 gripped at a level that differed from the desired level of effort by an average of only 5.2, 4.6, and 3.8%, respectively, during the three check-up sessions, while subjects in Group 3 gripped at a level that differed from the desired level of effort by an average of 12.8, 12.4, and 10.3%, respectively (Table 2).

Resting HR and BP were not significantly changed as a result of the training regime in either Group 3 or Group 4. There were no differences between Group 3 and Group 4 in baseline HR and BP over the six-week supervised training period. There were no significant differences in training HR or BP between Group 3 and Group 4 during the six-week supervised training period. Heart rate and BP responses to the exercise effort were unchanged within Group 3 and Group 4 during the six-week training period. During the six-week maintenance period following the supervised training period, resting HR and BP remained unchanged from initial resting levels in both Group 3 and Group 4, and there were no differences in resting HR and BP between Group 3 and Group 4.

At-home training logs were collected from all subjects at the conclusion of the study. All subjects reported completing 15 training sessions on their own. In addition, all subjects met with the investigators 3 times (once every 2 weeks).

DISCUSSION

The task of squeezing a handgrip dynamometer at a prescribed level of tension is learned easily (Rosen et al. 1991). The goal of this study was to examine how well this learned behavior could be transferred to a less expensive piece of equipment without loss of grip ten-

Table 2. Percent difference (absolute value) from desired level of contraction effort for subjects during three check-up sessions within a six-week maintenance period following six weeks of isometric exercise training using a handgrip dynamometer. Subjects in both groups were gradually introduced to a substitute item during the initial training period and used only this item during the maintenance period. Subjects in Group 3 (n = 10) used an egg-shaped substitute item while subjects in Group 4 (n = 10) used a fitness grip which more closely resembled the shape of the dynamometer. Check-up sessions were scheduled approximately every two weeks during the maintenance period. Values expressed as mean ± standard error of the mean.

Study Group	Check-up #1	Check-up #2	Check-up #3
3	12.8 ± 4.7	12.4 ± 3.8	10.3 ± 1.9
4	5.2 ± 1.8	4.6 ± 1.0	3.8 ± 0.8*

*Significantly different from Group 3, $p = 0.0047$.

sion and the consequent loss of benefits from a regular isometric exercise regime. The results of this study suggest that the gradual introduction of a substitute item that is similar in shape to the handgrip dynamometer is beneficial to this process.

The ability to squeeze a handgrip dynamometer at a desired level of effort requires the subject to be able to discriminate muscle tension. Muscle tension may be directly measured by means of electromyograph (EMG), and this method is commonly used in studies where muscle tension discrimination is involved (Flor et al. 1992, Grazzi and Bussone 1993, Smirnov and Kozlovskaya 1990, Utz 1994). Forearm muscle tension, however, is prone to artifact (Waters et al. 1987), and, for this reason, was not measured by EMG in this study. Instead, level of effort was confirmed by direct measure from the dynamometer coupled with cardiovascular measures. A classic adaptation to regular exercise training is a decreased cardiovascular response to exercise performed at the same absolute level of effort (Clausen 1977, Scheuer and Tipton 1977). If the training regime had involved this type of effort, the cardiovascular measurements would not have served a useful role in this study. Under the conditions of this study, however, the cardiovascular measurements (HR and BP) provide a valid index of level of effort because training was performed at the same relative level of effort each time. Although an increase in forearm strength was observed in most subjects as indicated by a gradual increase in MVC, the cardiovascular responses to gripping at a 30% MVC effort did not change significantly. Therefore, the cardiovascular parameters measured in this study served as a reliable index of the subject's level of effort.

It is not clear to what degree the success of this study was based on the instructions given to the subjects. Numerous studies have focused on the role of the instructions given to subjects and the results are mixed. Some have concluded that the instructions were incidental to the outcomes (Blanchard et al. 1974, Suter et al. 1983) while others have suggested that the instructions were critical to the outcomes (Carlson 1982, Yates 1980). A study specifically aimed at examining the role of the instructions given to subjects during EMG biofeedback found that most subjects adopted a "feedforward" type of strategy to learn the task regardless of whether or not they received instruction or the type of instruction given (Utz 1994). This study also suggested that, because the goal of the study (lowering forehead EMG levels) was inherent based on the surroundings and types of measurements, even those subjects who received no instructions on how to lower forehead EMG demonstrated a reduction in forehead EMG. The goal of the present study was explained to all subjects at the beginning of the study, so each subject had some inherent instructions. This may have contributed to the observation that significant differences in gripping at the desired level of effort were not evident between the two groups until 6 weeks following completion of the formal training period.

It is likely that the gradual introduction of the substitute item, coupled with the instructions concerning cardiovascular responses, contributed to the success of this study. One comment that many subjects in Study I had concerned the very different shape and feel of the substitute item compared to the handgrip dynamometer, and these comments were the basis for Study II. The 2-week acclimation period Group 2 subjects had with this substitute device prior to performing the exercises completely on their own contributed to their familiarity with the desired level of effort on this device and appears to have allowed them to retain this learned response for a longer period of time compared with Group 1 subjects.

It is doubtful that the different proportion of female to male subjects in the two study groups (78% of the subjects in Study I were female, while only 45% of the subjects in Study II were female) adversely affected the outcome. Studies examining grip deficit have indicated that such factors as handedness and mental illness (such as schizophrenia) affect the ability of an individual to grip at a desired level of effort (Rosen et al. 1991). In addition, motivation is a large factor in performing this type of activity as persons who are mentally depressed exhibit grip deficit (Cohen et al. 1982). No studies, however, have indicated any differences related to the sex of the subjects.

While it is hoped that this type of exercise regime may be an appropriate treatment for many persons afflicted with mild hypertension, there are some persons with other ailments who may not be able to perform this type of exercise properly. For instance, a person may suffer from both hypertension and some type of chronic pain in the wrist or hand region. If the chronic pain is due to increased muscle tension, then isometric exercise may not be an appropriate treatment method. In Study I, a 24-year-old female was allowed to withdraw from the study after completing 2 weeks of the training after reporting prolonged and excessive pain in the exercising arm which persisted for hours following each exercise session. Clearly this type of exercise training was inappropriate for her. In addition, there is evidence that persons who suffer from chronic pain due to increased muscle tension are deficient in their ability to discriminate tension in the affected muscles compared with healthy subjects (Flor et al. 1990, Flor et al. 1992, Grazzi and Bussone 1993). Specifically, chronic pain patients perceive higher EMG levels as less muscle tension than healthy controls

(Flor et al. 1992). This deficiency should be considered when deciding on an appropriate treatment plan as persons who suffer from chronic pain in the hand or wrist region may not be successful in this type of training program. Aside from persons with these kinds of conditions, this type of exercise regime may prove to be an inexpensive, convenient, and successful treatment for many persons who suffer from mild hypertension.

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