Effects of Prosthetic Training on Upper-Extremity Prosthesis Use

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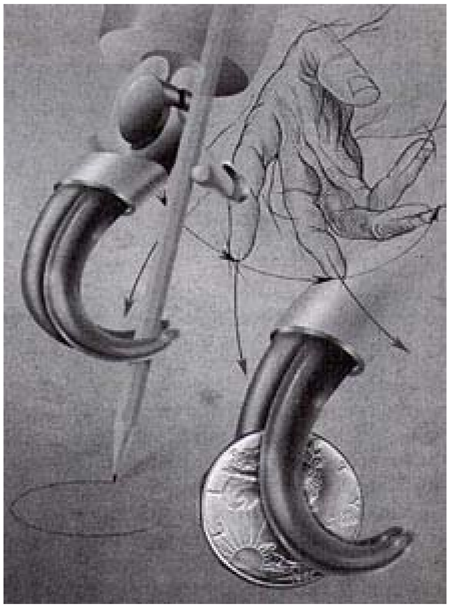
ABSTRACT

A study was conducted to determine the benefits of prosthetic training for a person using an upper-extremity prosthesis. Ten individuals without amputations were randomly assigned to either a training or nontraining/control group. Since these individuals were not amputees, they were fitted with bilateral training prostheses.

The training group was involved in a training program administered by the researcher in which the participants took advantage of various tools (blocks, paper, pencils, clothes and hangers) to learn how to use upper-extremity prostheses. The control group received the same tools and performed the same activities as the training group, but members were not trained in the same manner as those in the first group.

Subjects were involved in four sessions of approximately two hours each. Pre- and post-tests determined the prog- ress of the subjects. In addition, all subjects were required to complete four additional tasks to determine if the groups would apply what was practiced in the sessions.

The University of New Brunswick Test for Prosthetic Function was adapted for assessment of prosthesis use. Statistical analysis was accomplished through the use of the Mann-Whitney U Test (Wilcoxon Rank Sum Test). The individuals who received training performed tasks in a skillful, efficient manner, exceeding the performances of the untrained group.



Introduction

Hands play a unique and important role in a person's life; they serve prehensile, proprioceptive and communication purposes (1). Loss of one or both hands requires an individual to make changes in his or her performance of activities of daily living.

Few studies have investigated the relationships among upper-extremity amputation, prosthetic training and overall acceptance of the prosthesis. However, one well-known observation is individuals with upper-limb loss who are fitted within 30 days of amputation are more likely to accept prostheses than those fitted after 30 days (2).

Differences between unilateral and bilateral amputees have an important consequence on acceptance. Unilateral amputees tend to master tasks with one hand, rejecting prostheses, as opposed to bilateral amputees, who require prostheses for some prehensile activities (3).

In investigating patterns of acceptance and rejection of upper-limb prostheses, Burrough and Brook (4) stated. "Counseling to help the recipient develop realistic expectations about the capabilities of the prosthesis and adequate training in the use of the prosthesis after it has been fitted seem to be priorities for upper-limb amputees if the unacceptably high rejection rate is to be reduced." Case studies also have noted the value of comprehensive training programs for upper-extremity amputees (5,6).

The impact of prosthetic training was noted in a Canadian study involving 26 upper-limb amputees. It was found that in a group of individuals who received training, "90 percent used their prosthesis in a functional way. Only 50 percent of those in the group who did not receive training used their prosthesis functionally" (7). From the previous literature, one can determine that prosthetic training, as well as duration after amputation and counseling, influences the overall acceptance of the prosthesis.

Researchers had yet to investigate the functional differences between trained and untrained individuals involved in a controlled setting. This study strives to fill this void in the literature.

Methodology

Sample

Subjects were selected from a sample of convenience consisting of 16 nonamputated individuals. From the volunteer group, 10 subjects met the inclusion criteria and were randomly assigned either to the experimental or control group; each group included five subjects. Assignment was performed by drawing subject names from a hat and assigning each to a respective group by alternation, starting with the training group. Inclusion in the study required that the individuals be available for testing; have no previous knowledge of upper-extremity prosthetics; and have no back or skin problems that might affect the wearing of the training arm or use of the harness system.

The subject population consisted of four males and six females with an age range of 22-64 years (mean age = 48.5). Eight subjects were right-handed, and two were ambidextrous. After random assignment, each group consisted of two males and three females. Mean ages of trained and untrained groups were 53 and 43, respectively.

Design

Before this study could be conducted, several issues were addressed, the first being subject population. Time and geographical constraints made it impossible to locate 10 amputees who could take part in this study. Instead, 10 nonamputated individuals were fit with bilateral training arms (See Figure 1) . The training arms were fabricated from positive models of the subject's forearm and hand. Fabrication also included drape-molded 3/16-inch polypropy-lenea and used USMC componentsb. Each set of training arms used bilateral flexion wrists, aluminum voluntary opening hooks and a figure-eight harness with Northwestern Ring. All subjects were cast, fitted and harnessed prior to testing. Subjects were fitted bilaterally so mastery of the control of the prostheses would be needed to complete different tasks. If the subjects were fitted unilaterally, the "sound hand" would be used, which in turn would introduce additional variables and complicate the grading process.

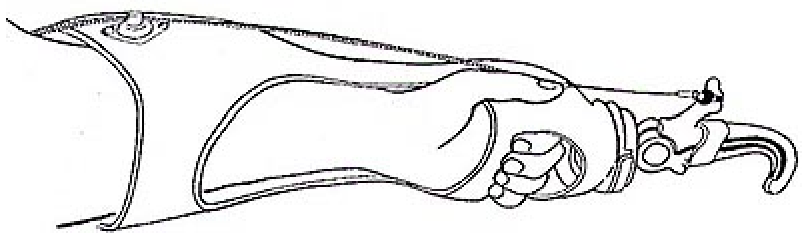


Figure 1. Training arm worn by nonamputated individuals during the study.

The second issue addressed prior to the start of the study was the design of the training program. Guidance from a functional bilateral transradial amputee (9), as well as occupational therapists at The Institute for Rehabilitation and Research in Houston (10), aided in the development of the training program. Program design also was influenced by research of relevant literature (8,11,12).

Assessment of Function

One other issue that had to be decided before the study began was the grading of the subjects' progress. Some methods of grading rate how fast an individual can perform a task or his or her ability to complete a task. Other methods consider the individual's ability to perform a single task, perhaps stacking blocks, to assess function (13). The grading of function is a difficult job; improved function is not necessarily evident in faster times of completion or ability to complete a single task. Evaluating upper-extremity prosthetic function involves examining the manner in which the prosthesis is used in the manipulation of a task. The University of New Brunswick (UNB) Test of Prosthetic Function was determined to be an appropriate manner in which to grade function for this project.

The UNB test was designed to determine the progress of a child during functional training. It primarily is used with pediatric unilateral myoelectric prosthesis users. Due to this specific amputee population, minor modification was made to the grading scales for application to the bilateral, conventional, prosthesis-wearing sample. The test has a dual rating scale that measures prosthetic function/skill and spontaneity. Spontaneity is defined by the UNB authors as "the tendency to use the prosthesis . . . without conscious effort, as automatic as the sound hand" (13).

Function consists of several factors, including ability to open and close the terminal device, ability to grasp and release different-sized objects, quick and consistent motions during the manipulation of objects, and maintenance of grasp in carrying or hand-to-hand activities (e.g., passing a pencil between the terminal devices).

The author found it necessary to add an additional column on "efficiency of prosthesis use" to the grading scale. This investigates four additional aspects of conventional use not addressed in the dual scale of the UNB:

1. using tension only when opening the terminal device (constant tension will increase muscle fatigue and soreness);
2. appropriate prepositioning, which provides for easier manipulation and the elimination of

gross body movements;
3. positioning the task; and
4. using the environment for ease of manipulation (e.g., sliding a quarter to the edge of a table to allow for easier prehension).

Incorporation of these aspects into the UNB dual rating scale would have involved excessive modification, compromising the validity of the scale. Subjects were given one point for each of the aspects demonstrated. (See Figure 2 for the scales used in this study.)

Spontaneity of Prosthesis Function

Score	
4	Immediate, automatic, consistent use of terminal devices for active grasp
3	Slightly delayed or inconsistent use of terminal devices for active grasp
2	Very delayed, occasional use of terminal devices bimanually. One terminal device is consistently used actively, the other passively.
1	One terminal device is always used for active grip and the other as a passive stabilizer.
0	Both prostheses are used passively—that is, no or very little terminal device opening or closing.

Skill of Prosthesis Function

4	Active use of terminal device is quick, skilled and smooth. Bimanual motions are performed. Grasp is consistently maintained.
3	Active use of terminal device, shows some degree of awkwardness, slowness or uncertainty. Grasp is readily regained if lost.
2	Active use of terminal device is attempted but looks very slow or awkward. Grasp is sometimes lost and readjusted (difficulty in release).
1	Mostly passive use of prostheses. Active use only as a last resort.
0	Prostheses are used passively.

Efficiency of Prosthesis Use

- Tension in cabling only when appropriate.
- Prepositions hook and wrist when appropriate.
- Position task/object to be manipulated.
- Use of environment or self to aid in completion of task.

Figure 2. Grading scale used in the study.

Procedures

Subjects were divided into two groups: trained and untrained. Training arms were delivered two days prior to the session start date. At delivery, proper adjustments were made to the fit and function of the training arms to allow for comfortable, efficient use of the prosthesis. Methods of donning/doffing, prepositioning and control were taught to the subjects, and each subject demonstrated these processes to the researcher. Since the sessions took place in the individuals' homes, measures were taken to create an identical environment among subjects.

Subjects had access to the training arms only during the sessions so approximate time of use could be determined; skewing of the results could occur if subjects wore the training arms outside the sessions for varied amounts of time. A pre-/post-test design was incorporated to assess progress.

The first task involved stacking blocks along a flight of stairs (see Figure 3) . The subjects picked up two blocks, one in each terminal device, and separately placed each block on the stairs. This task required the subject to maintain grasp with one terminal device while opening the other terminal device. As the subject moved up the stairs, the increasing distance made the task more difficult.

Figure 3. Subject performing the stairs and blocks task.

The second task (see Figure 4) , assembling notched sticks in a predetermined structure, required the individual to demonstrate smooth grasp and release with close attention to positioning of both the terminal device and the object to be manipulated.

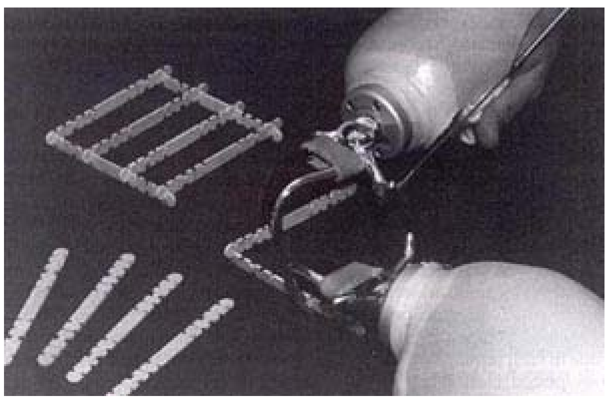


Figure 4. Subject performing the notched sticks task.

In the third task, grasp and release were further tested when individuals arranged dominoes in a predetermined pattern (see Figure 5) . The task became more difficult as the subjects worked their way around the board and the domino placement began to wind and become closer.

Figure 5. Subject performing domino task.

At this point, the training group was involved in a program as indicated in Figure 6 . Conversely, the untrained group received the tools to perform the tasks on a specific day without any instruction on how to complete the task. On day one, for example, a method for holding a pencil that ensures minimal rotation and maximum stability (see Figure 7) was explained and demonstrated to the training group. The untrained group was simply provided with the pencil and paper but received no instruction on how to use the prostheses to manipulate these items.

Day One
- Pretest
- Write name/alphabet
- Tear paper
- Carry cups of water
- Use ruler
- String beads (8-mm diameter)
- Grasp/release exercises

Day Two
Review blocks, writing, beads and hand-to-hand from previous day.
- Fasten buttons
- Peg board activities
- Color in coloring books
- Use clothes hangers
- Manipulate notched sticks
- Turn pages in a book
- String beads (5-mm diameter)
- Place folded paper in envelope
- Take objects off shelf
- Open candy
- Block manipulation

Day Three
Review of peg board, books, beads and hand-to-hand from previous day.
- Pour glass of water
- Write on an envelope
- Count change
- String beads (3-mm diameter)
- Fold paper

Day Four
Review of counting change, beads and hand-to-hand from previous day.
- Stack blocks
- Tie a knot
- Hang clothes
- Use a tape measure
- Apply a band-aid
- Write
- Place stamp on envelope
- Eat
- Post-tests
- Additional tasks

Figure 6. Day-by-day activities of the training group.

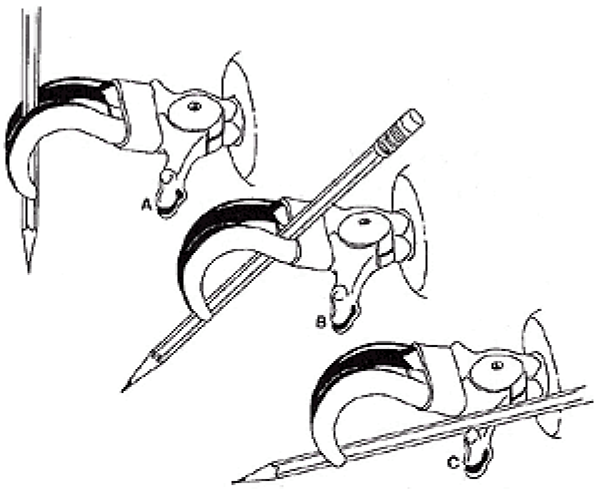


Figure 7. Holding a pencil with the terminal device is a difficult task. In "A" the pencil is not stabilized and is free to rotate in a clockwise direction. In "B" the pencil is stabilized against the tension band. In "C" the pencil is optimally stabilized against the thumb of the terminal device.

Each day built on what was learned the previous day. Several examples follow. The progression of stringing beads with smaller diameters required the individual to maintain a careful grasp of the bead. Due to the curvature of the beads, too much tension on the bead would cause it to shoot out of the terminal device.

The progression from grasp and release exercises to manipulating coins involved the refining of grasp with consistent tension. Using a pencil, coloring in a coloring book and using eating utensils further emphasized positioning of the terminal device and object to be manipulated. These tasks aided the subject in developing a proprioceptive sense of terminal device placement through shoulder motion. Finally, tearing paper, turning pages in a book, and tearing stamps and placing them on an envelope involved using the tip of the terminal device.

During the training sessions, the subjects were shown how to use the different parts of the terminal device. At all times, subjects in the training group were shown how to use either the environment (e.g., pushing a coin to the edge of the table to gain a better grasp) or themselves (e.g., using their chin when folding or hanging clothes or using their teeth when opening a candy wrapper) for assistance.

At the end of the fourth day, the subjects repeated the tests they attempted before the sessions. Four additional tasks also were introduced to each subject to see if they could apply what was learned or practiced during the sessions. The first task, opening an aspirin bottle, required the subject to use his or her teeth to remove the top. The second and third tasks involved folding a bath towel and placing coins in a slot. These two tasks could easily be performed if proper positioning and use of the environment were demonstrated. The final task (see Figure 8) , placing 1/4-inch washers on 1/4-inch dowels, served as an advanced task in prepositioning and grasp and release. In this task, the subjects were not allowed to rotate the object, which made proper placement of the washer more difficult.

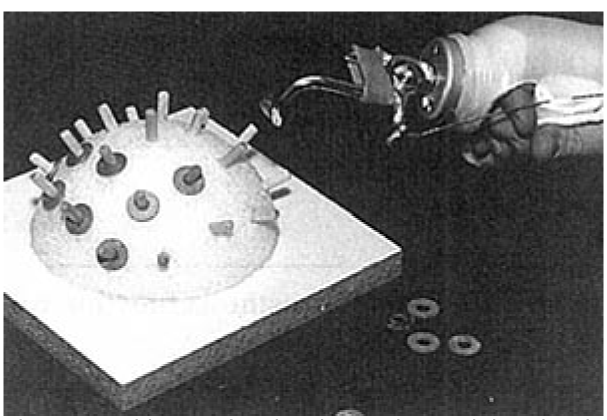


Figure 8. Subject performing the washer and dowel task.

Data Analysis

Data analysis was performed using the Mann-Whitney U Test (Wilcoxon Rank Sum Test). Pretest and post-test differences were compared between the two groups. Pretest scores between the groups were found to be consistent, indicating all individuals were closely matched in skill level prior to the sessions. Differences between the groups were analyzed in regard to the additional tasks. A p value equal or less than 0.05 was deemed significant.

Results

Mean pretest scores and post-test improvement were calculated and plotted in charts for spontaneity, skill and efficiency of prosthetic function/use (see Figures 9 , 10 , and 11). When looking at differences between groups, the following was observed. Significance in spontaneity was found only in the domino board task (p=0.004). Significance in skill was seen in the stairs and blocks task (p=0.03). Significance in efficiency was noted in both the stairs and blocks task and the domino task (p=0.006 and 0.04, respectively). The charts indicate the trained group, in almost all cases, showed improvement over the untrained group, but statistical significance was not attained.

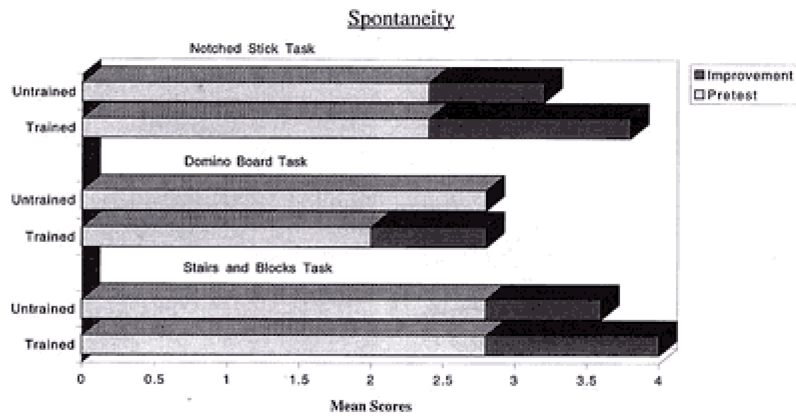


Figure 9. Spontaneity of prosthesis function results.

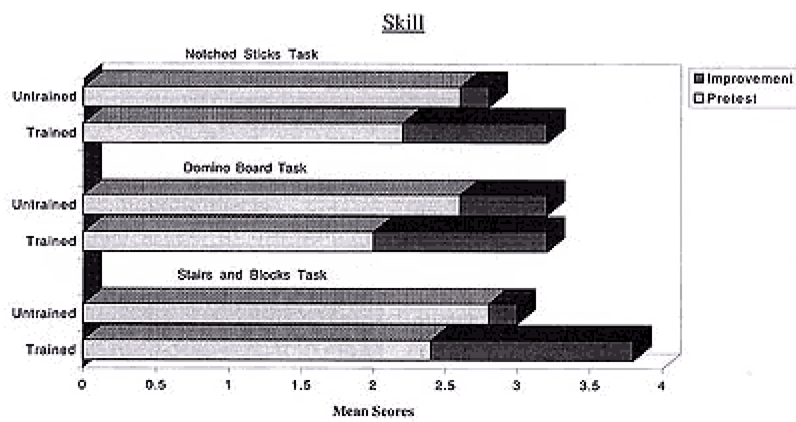


Figure 10. Skill of prosthesis function results.

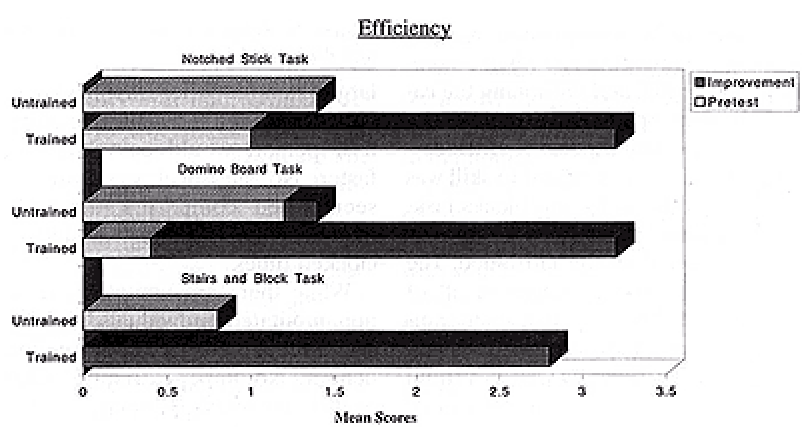


Figure 11. Efficiency of prosthesis use results.

Analysis of the additional tasks showed significance in spontaneity in regard to folding a towel (p=0.01) and opening an aspirin bottle (p=0.003). Skill results were significant in folding a towel (p=0.05) and near significant in the dowel and washer task (p=0.09). Finally, significance in efficiency was noted in folding a towel and opening an aspirin bottle (p=0.01) as well as in the dowel and washer task (p=0.02).

Discussion

In this study, greater improvement was noted within the trained group in regard to efficiency and skill. Skill is directly influenced by the level of efficiency with which a task is performed. Prepositioning the terminal device and the object to be manipulated, making use of environment or self when manipulating an object, and tensioning the cable only when opening the terminal device are important aspects of efficiency.

The significance in regard to skill was seen only in the stairs and blocks task, but it is evident the trained group performed better than the untrained. The lack of significance throughout all of the tests probably is due to a small sample size. Since there were several incidences of significance as well as a trend indicating the trained group performed better, it is reasonable to assume significance could possibly increase with a larger sample. Where applicable, individuals were unknowingly timed to see if a person would complete a task faster. No statistical significance was seen when comparing times-most likely due to the high variabilities in clocked times.

While there are limitations to using nonamputated individuals in a study such as this, there is one very important benefit. No upper-extremity amputee would have sacrificed training that could make a significant difference in the level of function he/she could attain for the purpose of this research. It was evident from discussion with the untrained group that these individuals at times became discouraged when attempting tasks using the training arms. This discouragement could have led to rejection of the prosthesis in an actual upper- extremity amputee. These training arms are a valuable tool for researchers, therapists and prosthetists.

Conclusion

The literature advises the immediate management of the amputee so acceptance will be high. During this period of high acceptance, the amputee might be more willing to try a prosthesis. A well-rounded rehabilitation program is equally as important as a well-made, properly fitting prosthesis. The quality of training will determine how the individual uses the prosthesis for the rest of his or her life.

As indicated in the results, training has a positive effect on function. For these reasons, training should be aggressively sought and required for nearly every new upper-extremity amputee.(5)

Acknowledgements

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