Intermanual transfer effects in novice and experienced below-elbow myoelectric prosthesis users

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Submitted for publication
ABSTRACT

**Background.** Intermual transfer training may be beneficial for persons with an upper limb amputation, since it facilitates prosthesis training shortly after the amputation. Intermual transfer implies improvement of skill in the affected arm, after training the unaffected arm. Previously, this has been demonstrated only in able-bodied persons for prosthetic skills.

**Objective.** To determine intermanual transfer effects in patients with a below-elbow amputation, in both experienced (experiment A) and novice (experiment B) myoelectric prosthesis users, and to establish whether laterality affects these effects.

**Design.** A: Case-control, B: Case-series.

**Methods.** A: Experienced myoelectric prosthesis users (n=22) and matched controls (n=22) performed tasks using a prosthesis simulator attached to their non-affected arm. Outcomes were movement time, force control, Box and Blocks test (BBT)- scores and duration of hand opening. B: A training group of novice myoelectric prosthesis users who trained using the simulator (n=3) were compared to a control group of novice users who did not train (n=4). Group-allocation was randomized. Movement time and force control were measured in the affected arm using the patient’s own prosthesis.

**Results.** Movement times of experienced (A) and trained novice (B) myoelectric prosthesis users were shorter. Experienced users (A) had a higher BBT-score and a shorter hand opening duration compared to controls. No intermanual transfer effects on force control and no laterality effects were found.

**Limitations.** Blinding was not feasible, and only few novice users were measured.

**Conclusions.** Intermual transfer effects were present after training in persons with a below-elbow amputation, independent of laterality. This is of clinical relevance for persons with an upper-limb amputation, for it supports the idea that prosthesis handling benefits from intermanual transfer training shortly after the amputation.
INTRODUCTION

Persons with an upper limb amputation reject their prosthesis in approximately 20-40%, because of a low degree of functionality.\textsuperscript{1, 2} To reduce this high percentage of refusal, one can improve the design of the prosthesis. Another way is to improve the handling of the prosthesis, which can be established by training.\textsuperscript{18, 126} Starting prosthetic training early after the amputation, preferably within the first four weeks, could result in better acceptance and handling of the prosthetic device.\textsuperscript{6, 9, 26} A problem of training immediately after the amputation is that the wound on the stump is not yet healed and the stump contains edema. Furthermore, the prosthesis needs to be constructed and fitted. For these reasons, most of the patients can only be fitted with a proper myoelectric prosthesis a few months after the amputation.

To improve prosthetic handling immediately after the amputation, intermanual transfer might be useful.\textsuperscript{18, 61, 71, 95} Intermanual transfer means that a motor skill trained in one arm, also improves in the other arm.\textsuperscript{13, 28-30} When applying intermanual transfer immediately after an upper-limb amputation, the unaffected arm can be trained in prosthetic skills using a prosthesis simulator immediately after the amputation. A simulator is operated in the same way as an actual prosthesis, but is worn on the unaffected arm.

In several previous studies, intermanual transfer effects in learning to use a prosthetic device were found.\textsuperscript{18, 61, 71, 95} However, these studies used able-bodied participants and to this date no studies on transfer of prosthesis skills have been conducted with persons with an upper limb amputation. It is expected that after an intermanual transfer training the performance with the actual prosthesis will be enhanced. However, it is hard to find enough novice amputation patients to set up a study that reaches sufficient statistical power because the incidence of upper limb amputations is low. We therefore also examined experienced prosthesis users, because it may be assumed that prosthetic users have extensively trained the skills to handle a prosthesis at their affected side through the use of their own prosthesis. If these skills transfer to the other side, the prosthesis skills of the unaffected arm probably will be better than those skills in non-amputee novice prosthetic users (reverse effect).

The aim of this study is to determine whether intermanual transfer effects can be demonstrated in persons with a transradial or wrist
disarticulation amputation, in experienced (experiment A) as well as novice (experiment B) myoelectric prosthesis users. If the intermanual transfer effect is present, we expect a) movement times to be faster, b) force control to be more proficient, c) prosthesis handling to be more dexterous or d) duration of hand opening to be shorter in trained participants than in controls. These hypotheses are based on findings in previous studies. 18, 61, 71, 95 Further, if intermanual transfer effects are present, a secondary aim of this study is to establish whether laterality is of influence. Most previous studies show that intermanual transfer effects are larger from the dominant side to the non-dominant side, 11, 14, 41, 47, 48, 51, 68 others demonstrate that the reverse is true 50 and finally there are also studies which did not find any influence of laterality. 16, 18, 61, 95

METHOD EXPERIMENT A

Participants

Experimental group
Experienced myoelectric prosthesis users, either right or left-sided, were measured at the INAIL Centro Protesi (Budrio, Italy) between November 2014 and March 2015. These users were either persons with an amputation, or persons with congenital transversal reduction deficiencies, at transradial or wrist disarticulation level. Inclusion criteria were: at least two months experience with a myoelectric prosthesis, using the prosthesis at least three days per week, one hour per day for the last month. Exclusion criteria were: known neurologic problems, no normal or corrected to normal sight and earlier experience with the prosthesis simulator on the unaffected arm.

Control group
Matched controls (lower limb amputees and employees of INAIL) with sound upper limbs were measured in the same time period and at the same location as the experimental group, except for two controls, who were measured in the Netherlands in March 2015. All controls matched on sex, age (+/- 5 years) and hand dominance with the patients of the experimental group. Exclusion criteria were the same as for the experimental group.

Design overview

Both the experimental and control groups started the experiment with the completion of a questionnaire. Subsequently, they completed a test
to measure the prosthesis skills of the unaffected arm using a prosthesis simulator. The test arm of the controls was comparable to the test arm of the matched experimental participant: If the right arm of the participant was tested, the right arm of the matched control person was tested. Also (pre-amputation) hand dominance was matched. The Medical Ethics Board of the UMCG approved the design of experiments A and B (NL 35268.042-11). All participants signed an informed consent document before participation.

**Materials**

A questionnaire consisting of demographic questions, a pre-amputation hand-dominance inventory (Edinburgh Handedness Inventory) and questions about prosthetic use was filled out. The controls completed a shortened questionnaire, with only the relevant items on demographic data.

Two myoelectric prosthesis simulators were manufactured by OIM Orthopedics (Haren, The Netherlands); one for training a left hand and one for training a right hand (Figure 1). The simulators consisted of an open cast made of carbon. At the distal end, a MyoHand VariPlus Speed (Otto Bock, Duderstadt, Germany) with proportional speed-control (15-300 mm/s) and proportional grip force control (0-±100 N) was attached. The cast extended on the proximal end into a splint along the forearm, that was adjustable in length and that could be attached with a Velcro sleeve. With this splint, two electrodes were placed on the muscle bellies (wrist flexor and extensor) of the forearm,

![Figure 1. The prosthesis simulator with the potentiometer attached. The Box and Blocks Test is visible at the background.](image-url)
which were used to control the prosthesis hand by detecting changes in electrical activity related to muscle contraction.

A MyoBoy (757M11 MyoBoy; Otto Bock, Duderstadt, Germany) was used to determine the sensitivity of the electrodes.

E-Prime (Psychology Software Distribution, York, UK), an application suite, was used to register movement time.

A custom made program created with Labview (display and sample frequency 100 Hz) was used to measure the amount of force when pinching a handle (Figure 2). The handle consisted of two plates with a force transducer (LLB350 Loadcell (Futek)) placed in between.

A standard Box and Blocks Test (BBT) was used. The BBT is a widely used instrument to assess gross hand dexterity. The participant has to transfer as many 2.5 x 2.5 cm blocks from one box to another within one minute (Figure 1).

A potentiometer was used to measure the hand opening. One small rod was attached to the base and another rod to the wiper. The two rods were attached to the prosthetic hand: one to the thumb and the other

Figure 2. a.) Force handle for measuring force control. The thumb of the simulator-hand was placed on the front plate and digits 2-5 on the posterior plate, so that the handle could be pinched. b.) On-screen tracking pattern. The blocked yellow line is the computer-generated pattern; the red line is the participant’s produced force while pinching the handle.
to the index finger. The output of the potentiometer was digitally sampled with a DAQ-device (National Instruments, Austin, Texas, USA) that was attached to a laptop.

**Interventions**

The test took place in a standardized setting in the clinic. Before starting the experiment, the participants signed an informed consent, filled in the questionnaire, and it was explained and demonstrated what was expected of them. Next, the simulator was fitted: after palpation of wrist extensor and flexor muscles, the electrodes were placed. Measuring with the MyoBoy, the amplified signal of the electrodes had to exceed a threshold of 1.5 V (high signal), which had to be sustained for two seconds. The maximum speed of the hand was set to the default setting of six (double channel control, fast open and slower closing). After the simulator was fitted, the participant was positioned in front of the table with the elbow 90 degrees flexed.

**Test**

The test consisted of a functional test (Test block 1), a force control test (Test block 2) and a BBT test (Test block 3). Test blocks 1 and 2 were executed in random order and Test block 3 was always executed at the end. This was to avoid influence of learning effects of the BBT on the functional and force control tasks because the BBT has a duration of one minute, and the other tasks only took several seconds to complete. All tasks were repeated three times. Test block 1 consisted of three direct-grasping tasks with different grasping patterns. These tasks were: 1) mug-task: picking up a mug by the handle and placing it 25 cm above the table on a shelf using an extension grip; 2) ball-task: picking up a tennis ball and placing it in a mug using a power grip and 3) zipper-task: open/close a fixed zipper using a tripod grip. A computer with E-Prime showed in random order which task had to be executed. Before and after each task the participant pressed the spacebar on a keyboard that was positioned at the test side, to measure movement time. During the mug task the duration of the hand opening was recorded using the potentiometer. During the force control test of Test block 2, the participant had to track a target line shown on the screen, using a custom made program. By pressing a handle, the cursor height could be adapted, which was visible through a second line on the screen (Figure 2).
Outcomes

Outcome measures were: 1) movement time, the time in milliseconds from the beginning of the movement until completion of the task; 2) force control, the difference between the required and the applied force in N; 3) score on the Box and Blocks Test (BBT) in blocks/minute and 4) duration of hand opening in milliseconds.

Statistical Analysis

Statistical analysis was performed using SPSS 16.0 software package (IBM Corporation, Armonk, NY, USA). All outliers that deviated more than three times the standard deviation were removed. The means of the three trials of each task were calculated. Missing values were replaced by using the expectation maximization algorithm. For analyzing the functional tests, z-scores were used which were calculated for the three grasping tasks. A repeated measures ANOVA over the movement times with task (mug, ball, and zipper) as within-subject factor and training (experimental group and control group) and hand dominance (dominant hand is test hand and non-dominant hand is test hand) as between-subject factors was calculated.

The means of the error of the force control of the three trials of the tracking task were calculated. A univariate ANOVA was used to calculate the difference in the error of the force control with training (experimental group and control group) and hand dominance (dominant hand is test hand and non-dominant hand is test hand) as between-subject factors.

The means of the BBT-score of the three trials were calculated. An univariate ANOVA was used to calculate the difference in the BBT-scores with training (experimental group and control group) and hand dominance (dominant hand is test hand and non-dominant hand is test hand) as between-subject factors.

The duration of the hand opening was calculated using Matlab R2007a (MathWorks, Natick, MA, USA). The angle of the hand opening was measured and filtered with a 20 Hz cut-off frequency using a recursive second-order Butterworth filter. To obtain the velocity of the hand aperture, the opening profile was differentiated with a three-point difference algorithm. The peak values of this velocity profile were used to determine the hand opening and closing. By searching backward and forward from the peak value for the first value that was below a threshold of 2.5 cm/s and stayed there for 50 ms, the end of the first
hand opening and start of the hand closing were defined. The period between these points was taken as the duration of the hand opening. The means of the duration of the hand opening for the three trials were used during the analysis. Due to technical problems this variable was not measured with all participants and therefore a different analysis as with the other variables was performed. Using a comparison of the 95% confidence intervals of the experimental group and the control group, it was examined whether these two groups differed.

When sphericity was violated, the degrees of freedom were adjusted with the Greenhouse-Geisser correction. A significance criterion of 0.05 was used during the analysis. Post-hoc tests used a Bonferroni correction.

Role of the funding source

This study was supported by grants from Fonds NutsOhra, Revalidatiefonds, Stichting Beatrixoord, ISPO Netherlands and OIM Stichting. None of the funding agencies had any influence on the design and conduct of the study, the collection, management, analysis, and interpretation of the data, nor on the preparation, review, or approval of the manuscript.

RESULTS EXPERIMENT A

A total number of 23 experienced prosthesis users were measured, of which one was excluded because in retrospect he did not meet the inclusion criteria. Further, 23 control persons were measured. Of them, also one was excluded, for he did not match with his experimental counterpart. Therefore, a total number of 22 experienced patients and 22 matched controls were analyzed (all males, Table 1).

Table 1. Patient characteristics of participants of experiment A.

<table>
<thead>
<tr>
<th></th>
<th>Experimental group (N = 22*)</th>
<th>Control group (N = 22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years): Mean (SD)</td>
<td>49.23 (12.29)</td>
<td>49.36 (11.96)</td>
</tr>
<tr>
<td>Range</td>
<td>24-75</td>
<td>26-73</td>
</tr>
<tr>
<td>Test hand: R / L (N)</td>
<td>15 / 7</td>
<td>16 / 6</td>
</tr>
<tr>
<td>Hand dominance: R / L (N)</td>
<td>21 / 1</td>
<td>22 / 0</td>
</tr>
</tbody>
</table>

*: 21 patients with an amputation, of which two at wrist level and 19 at transradial level; one patient with a congenital reduction deficiency.
N: absolute number, SD: standard deviation, R: Right, L: Left
Movement time
The main effect of training group on movement time was significant ($F_{1,40}=9.836$, $P<0.01$): the experimental group was faster than the control group (Mean(SE) movement times: 8484(622) ms and 11061 (622) ms, respectively; Figure 3a). Further, the interaction effect between training group and hand dominance was significant ($F_{1,40}=4.930$, $P<0.05$). Post hoc unpaired $t$-tests, using a Bonferroni correction, showed that the experimental group was faster with the dominant hand than the control group ($t_{12} = -2.252$, $P < 0.05$). No other significant effects were found.

Force control
No significant effect of training group on error of force control was found (Means(SE) of the error of force control: 13.32(1.05) N for the experimental group and 12.85(1.54) N for the control group, Figure 3b). No other significant effects were found.

BBT-score
The experimental group performed better on the BBT than the control group: Mean (SE) BBT-scores were: 13.69 (0.84) for the experimental group and 11.11 (0.77) for the control group (Figure 3c). This main effect of training group on BBT-score was significant ($F_{1,40}=8.388$, $P<0.01$). The interaction between training group and hand dominance was not significant.

Hand opening
Due to technical problems, hand opening was only recorded for 12 controls and five experienced patients. Mean duration of the hand opening for the control group was 1340.55 ms, with a 95% confidence interval of 1068.22–1612.89 ms. The upper bound of the CI of the experimental group was below the lower bound of the CI of the control group, indicating that experienced persons had a shorter duration of the hand opening (Figure 3d).

METHOD EXPERIMENT B

Participants
Adult persons with an amputation or persons with congenital transversal reduction deficiencies, at transradial or wrist disarticulation level, either right or left- sided, were included at different locations: at the University Medical Center (Groningen, The Netherlands) and De Hoogstraat Rehabilitation (Utrecht, The Netherlands) between
Figure 3. Results of experiment A for a). movement time, b). error of force control, c). Box and Block Test (BBT) and d). duration of the hand opening. Figures 3a,b,c show means and SE per group. Figure 3d shows the means and 95% CI for both groups. Significant results are marked with an *.

September 2011 and September 2014, and at the INAIL Centro Protesi (Budrio, Italy) between November 2014 and March 2015. They all were in the pre-prosthetic phase, awaiting their first ever myoelectric prosthesis. Exclusion criteria were similar to those of experiment A.

**Design overview**

Participants were randomly divided into two groups: an experimental group and a control group. In contrast to experiment A, no matching between those groups took place, so that as many participants as possible could be included. Before the prosthesis was fitted, a total of six training sessions were performed by the experimental group by using the myoelectric prosthesis simulator attached to the unaffected arm. The control group did not receive any training but only performed the test. During the tests, patients used their own newly received myoelectric prosthesis. All participants signed an informed consent document before participation.

**Materials**

The myoelectric prosthesis simulators, Myoboy, E-Prime- & Labview-software and the force handle were identical to those of experiment A. Next to the force handle, three different compressible objects were used to measure force control. Each of them consisted of two plates with a spring in between. This spring had either 1: a low-resistance (0.17 N/mm), 2: a medium resistance (0.57 N/mm) or 3: a high resistance (5.31 N/mm). A scale (in mm) on the objects was used by the test assessor to check the maximum compression.

The tasks of the Southampton Hand Assessment Procedure (SHAP)-kit (SHAP Business Enterprise, University of Southampton, UK) were used for the training. The SHAP is a standardized test-tool, consisting of both abstract object manipulation (12 tasks) and activities of daily living (14 tasks).

**Interventions**

**Training**

The training consisted of functional tasks (participants 1 and 2) or a combination of functional tasks and force control tasks (participant 3). Functional tasks were trained with the SHAP that was performed once in the first and last session, and twice in the sessions in between. Force control training consisted of the tracking task using the force handle
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(Figure 2), whereby three different patterns on a computer screen were tracked in random order for 10 minutes in total.

Test
The test consisted of a combination of functional tasks and force control tasks (see Table 2). These tasks were presented in random order and all were repeated three times. Because only two functional tasks were performed by all participants only these two grasping tasks were analyzed. These tasks were the mug task (experiment A), and a jar lid task. The jar lid task is an indirect grasping task, consisting of picking up a jar with the unaffected hand, passing it towards the prosthesis hand, and opening the lid with the unaffected hand. Furthermore, most participants performed the force control test with the compressible objects, and thus these tasks were also analyzed. The variation between the types of training and tests among patients follows from the different moments in time that the patients were included.

Outcomes
Outcome measures were 1) movement time and 2) force control, similar to experiment A.

Statistical Analysis
Only descriptive analyses were used (means) because the number of participants was small.

RESULTS EXPERIMENT B
Three patients (aged 18-40 years) were included in the experimental group and four in the control group (aged 19-68 years). Patients 1-5 were tested in the Netherlands, patients 6 and 7 were tested in Italy. All participants were amputated after a trauma, except for one person, who lost his arm due to an oncological reason. Table 2 presents the characteristics and test results of the included patients.

Movement time
When comparing the scores on the two functional tasks that all patients performed in the test (the mug task & the jar lid task), the experimental group was faster than the control group (Figure 4). However, variability between individuals is substantial.
Table 2. Patient characteristics and test scores of experiment B.
The Tasks-column shows the combination of tasks that were performed. Functional test scores are movement times in milliseconds, force control test scores are deformations in millimeters. All patients had a right-hand dominance.

<table>
<thead>
<tr>
<th>Patient number</th>
<th>Group</th>
<th>Gender</th>
<th>Age</th>
<th>Amputation side</th>
<th>Prosthesis type</th>
<th>Tasks (all 3x, random order)</th>
<th>Functional test scores</th>
<th>Force control test scores</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Otto Bock DMC, proportional two site control</td>
<td>Mug, jar lid, pen case, LR, MR, HR</td>
<td>Mug, jar lid, pen case, LR, MR, HR</td>
<td>Mug, jar lid, pen case, LR, MR, HR</td>
</tr>
<tr>
<td>1</td>
<td>E</td>
<td>M</td>
<td>26</td>
<td>R</td>
<td></td>
<td>5296</td>
<td>4651</td>
<td>10.83 4.83 0</td>
</tr>
<tr>
<td>2</td>
<td>E</td>
<td>F</td>
<td>18</td>
<td>R</td>
<td>Touch Bionics i-Limb</td>
<td>7329</td>
<td>4998</td>
<td>17.33 21.00 0</td>
</tr>
<tr>
<td>3</td>
<td>E</td>
<td>F</td>
<td>40</td>
<td>L</td>
<td>Otto Bock DMC, proportional two site control</td>
<td>7877</td>
<td>5930</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>C</td>
<td>M</td>
<td>68</td>
<td>R</td>
<td>Otto Bock DMC, proportional two site control</td>
<td>12524</td>
<td>13056</td>
<td>20.00 19.30 13.23</td>
</tr>
<tr>
<td>5</td>
<td>C</td>
<td>M</td>
<td>19</td>
<td>R</td>
<td>Otto Bock DMC, proportional two site control</td>
<td>7777</td>
<td>6195</td>
<td>9.03  8.03 0</td>
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<tr>
<td>6</td>
<td>C</td>
<td>M</td>
<td>38</td>
<td>R</td>
<td>Be-Bionic</td>
<td>12012</td>
<td>17698</td>
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<tr>
<td>7</td>
<td>C</td>
<td>M</td>
<td>26</td>
<td>L</td>
<td>Otto Bock DMC, proportional two site control</td>
<td>6059</td>
<td>5409</td>
<td></td>
</tr>
</tbody>
</table>

*: patient 3 and patient 7 additionally performed 3x the tracking task with the force handle;
Force control
Mean deformation of the different deformable objects in the posttest was 9 mm for the experimental group (N=2) and 11.61 mm for the control group (N=2), indicating that the experimental group seems to perform slightly better than the controls.

DISCUSSION

This study is the first to show indications of intermanual transfer effects in persons with a below-elbow amputation. Movement times in experienced users and novice myoelectric prosthesis users after training were shorter compared to controls. Furthermore, experienced users were more dexterous, as reflected in better scores on the BBT, and their duration of the hand opening was shorter compared to the controls. No intermanual transfer effects were demonstrated for force control.

The intermanual transfer effect on movement time in experiment A is comparable to previous literature. In the study of Romkema et al (2013), the same type of simulator was used to complete three functional tasks that were comparable to the ones in the present study. In their study only able-bodied participants were used, who were much younger (mean age: 24.6 years). This might explain the
slower movement times we found in experiment A. Results of experiment B support the findings of experiment A: also novice prosthesis users seem to show an intermanual transfer effect on movement time. However, the latter finding should preferably be confirmed in a larger sample size.

The intermanual transfer effect on the BBT- scores in experiment A is a new finding: previous studies on intermanual transfer did not use this test as an outcome variable. However, several authors investigated prosthetic handling with the BBT: Experienced myoelectric prosthesis users using their own prosthesis (mean age 50.1 years) or healthy participants using a simulator (mean age 22 years) had mean scores of 15.3 and 17.4 blocks/minute, respectively.\textsuperscript{127, 128} These findings were higher than our mean score of 13.7 blocks/minute in experienced upper limb amputees, probably because the previous studies were executed with the patient’s own prosthesis instead of a simulator, used a body-powered simulator or concerned a younger test-population. It was found by Desrosiers et al (1994) that there indeed is a decline of BBT- scores related to age.\textsuperscript{129}

On discussing the results of the duration of hand opening, it has to be noticed that only a limited number of the participants and controls was measured on this parameter. Although with this limited data significant results need to be treated with caution, results are promising. All scores of experienced users were below the lower bound of the 95% CI of the control group, which indicates that there is indeed an effect of training group on duration of hand opening.

The finding that force control practice with the force handle did not show intermanual transfer effects is in accordance with previous studies.\textsuperscript{61, 71, 95} It is known that force control with a prosthesis requires a lot of training.\textsuperscript{67, 85} It was therefore hypothesized that more training results in better force control and in a possible intermanual transfer effect. In accordance with this hypothesis, we expected to find a difference in force control between the experimental and the control group in experiment A of the present study, because of the extensive training of the experienced patients in their daily life. The fact that we however did not find such results may be attributed to several factors. One of them is that although most patients report to wear their prosthesis the whole day, they use it in daily life mostly for tasks to assist their unaffected arm.\textsuperscript{42} This means that for more complex skills, like precise control of force, they prefer to use their unaffected arm, so that the prosthetic arm might be less trained than we expected it to be.
Because in literature about intermanual transfer the topic of laterality plays a major role, we analyzed whether this factor was of influence in experiment A. Results show that, although on the functional tasks dominant experienced users were significantly faster than dominant controls, no significant effect of laterality was present. Thus, the intermanual transfer effects appeared to be symmetrical and were not influenced by hand dominance. For the clinical setting this is an interesting result, for not only patients who have lost their dominant hand, but also those who have lost their non-dominant hand may experience advantages of intermanual transfer training.

A limitation of the present study is that in both experiments patients and researchers were not blinded, for this was not feasible in the design that was used. Another weakness is that the control group of experiment B did not receive a sham-training. From experiment B we learned that research projects like these, with a very specific inclusion group that is scarce, are hard to set up over a time period of several years. Moreover, training and test tasks varied too much over the participants, which hampered comparison between the novice users and also between novice and experienced users. The reason for these differences is that over time, we changed the design of the intermanual transfer training, based on results we found in other studies. Furthermore, matching the experimental group and control group appeared to be unfeasible, which resulted in a control group that varied from the experimental group in age, gender and hand dominance. This variability must be taken into account when interpreting the results of experiment B. Despite these limitations, results of experiment B were mostly supporting the results of experiment A, which is a strong indication that intermanual transfer effects are present not only in experienced, but also in novice myoelectric prosthesis users.

CONCLUSION

Intermanual transfer effects were present in experienced and novice patients with an upper limb amputation using a myoelectric prosthesis. However, transfer effects on force control were not found and need further investigation. Laterality did not play a role in the transfer effects. Our findings support the clinical relevance of intermanual transfer training, which may facilitate persons with an upper limb amputation to start training directly after the amputation.
ACKNOWLEDGMENTS

The authors want to thank Wim Kaan for his help with materials and software, Johan Horst and Theo Schaaphok from OIM Orthopedics Haren for their technical assistance with the simulators, and the people from the INAIL Centro Protesi for their help during the measurements.
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