Comparison of different myoelectric prostheses

Clinical Study Summaries

This document summarizes clinical studies conducted comparing different myoelectric prostheses. The included studies were identified by a literature search made on PubMed and within the journals Der Orthopäde, JPO Journal of Prosthetics and Orthotics, Orthopädie-Technik and Technology & Innovation.

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## 1 Overview table

The summaries are organized in three levels depending on the detail of information. The overview table (Level 1) lists all the relevant publications dealing with a particular product (topic) as well as researched categories (e.g. level walking, safety, activities, etc). Summaries of all the literature researching a specific question can be found in chapter 2 (Level 2).

For those interested to learn more about individual studies, a summary of the study can be obtained by clicking on the relevant reference (Level 3).

<table>
<thead>
<tr>
<th>Reference</th>
<th>Category</th>
<th>Prosthesis</th>
<th>Target group</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Author</strong></td>
<td><strong>Year</strong></td>
<td><strong>Body Functions</strong></td>
<td><strong>Activity</strong></td>
</tr>
<tr>
<td>Luchetti</td>
<td>2015</td>
<td>Mechanics</td>
<td>x</td>
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<td>Pröbsting</td>
<td>2015</td>
<td>Mechanics</td>
<td>x</td>
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<td>Major</td>
<td>2014</td>
<td>Mechanics</td>
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<td>Bertels</td>
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<td>Mechanics</td>
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<td>Cutti</td>
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<td>Beiter</td>
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<td>Mechanics</td>
<td>x</td>
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<td>Egermann</td>
<td>2009</td>
<td>Mechanics</td>
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<td>Bertels</td>
<td>2009</td>
<td>Mechanics</td>
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<tr>
<td>Lotze</td>
<td>1999</td>
<td>Mechanics</td>
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<td><strong>Total number</strong></td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
2 Summaries of categories

On the following pages you find summaries of specific questions researched in several studies. At the end of each summary you will find a list of reference studies contributing to the content of the particular summary.
Michelangelo Hand

Activity of daily life / Satisfaction / Technical aspects

**Major Findings**

With Michelangelo Hand compared to different myoelectric prostheses (Sensor hand speed; Myohand VariPlus Speed; Motion Control Hand; DMC plus Myohand):

- Higher manual dexterity is achieved (score of Box and Block Test increased by 20.8%)
- Perceived ease of use to perform ADLs increased by 35%.
- Hand is more actively used at home and the lateral grip is preferred in 77% of activities.
- Hand was used to actively grasp an object in more bimanual activities and it was 31% easier to perform the activities.

With Michelangelo Hand compared to Digital Twin Hand:

- Michelangelo hand reduces compensatory movements
- Patient is more satisfied with Michelangelo hand

With Michelangelo Hand compared to different myoelectric prostheses (Vincent hand; iLimb hand; iLimb Pulse; Bebionic hand; Bebionic hand v2):

- Michelangelo hand is the lightest and has the highest grip force
- Michelangelo advantage is in the low number of actuators with transmissions that allow all functional grasping postures

**Perceived difficulty of activities of daily life**

Perceived difficulty to perform 23 activities of daily living was measured with OPUS-UEFS questionnaire. Total OPUS-UEFS score was 26% higher with Michelangelo prostheses, meaning that tasks were easier to conduct with Michelangelo hand. (Pröbsting et al., 2015).

**Clinical Relevance**

Reporting frequency of prosthesis use in performing activities of daily life can provide information about prosthesis usefulness, satisfaction with the prosthesis and level of prosthetic skills.

Technical aspects of myoelectric prosthesis provide good insights of mechanical design and performance specifications. Best technical combination would achieve
high functionality, durability and adequate cosmetic appearance of the prosthesis as well as affordability.

**Summary**

Manual dexterity is the ability to make coordinated hand and finger movements to grasp and manipulate objects. The study by Luchetti et al., 2015 showed that the manual dexterity of Michelangelo hand is significantly improved when compared to single grip myoelectric hands (measured by standard tests: Box and Blocks test (B&B) showed 23%, Minnesota Manual Dexterity Test (MMDT) 15% and the Southampton Hand Assessment Procedure (SHAP) HAP 11% of improvement). Additionally, Michelangelo hand is more used actively at home, especially its lateral grip which is preferred grip pattern in 77% of activities.

Michelangelo prosthesis significantly reduces perceived difficulty of activities of daily living and improves function as compared to regular single grip myoelectric hands. Amputees use Michelangelo more often in bimanual tasks and to actively grasp an object than with standard myoprosthesis (Pröbsting et al., 2014).

Michelangelo hand is closing the gap between prosthetic and the sound side by reducing compensatory motion and bringing more natural movement to the patient. In addition, Michelangelo hand’s pleasant appearance brings more satisfaction to the users (Cutti et al., 2012).

A grip force of 68N is minimally required for human hand to carry out ADLs (Heckathorne et al., 1992), while prosthetic hands need a minimum grip force of 45 N for practical use (Vinet et al., 1995). The Michelangelo hand has the highest grip force in comparison to other myoelectric prosthesis (opposition grip force – 70N vs 34N the highest in other myoelectric; lateral grip force – 60N vs 20 the highest in other myoelectric) (Belter et al., 2011).

**References of summarized studies**


↑ Back to overview table
Compensatory movements when using myoelectric prosthesis

**Major Findings**

Compensatory movements with and without MovoShoulder Swing (with Dynamic-Arm and System Electric Hand):

- Compensatory movements during walking in shoulder, elbow and knee are reduced when using a free swinging shoulder joint
- Swinging of the sound arm in shoulder joint is 23% reduced
- Swinging of the sound arm in elbow joint is 13% reduced
- Unphysiological loading of the knee joint on amputated side is 12% decreased

Compensatory movements in myoelectric prosthesis users compared to able-bodied controls:

- Shoulder and trunk movements are common compensatory motions in prosthesis users.
- Increased variability in movement suggests that prosthesis users do not stick to a defined motor strategy.
- Kinematic repeatability may increase with prosthesis experience.

**Average range of motion for carton pouring task**

Upper body range of motion (RoM) was analysed on able-bodied controls and myoelectric transradial prosthesis users during execution of carton pouring task (lifting a carton, located at midline of the body, and emptying the liquid contents into a jar on the contralateral side with minimal spilling). Results indicate that prosthesis users demonstrate a significant increase in shoulder abduction, trunk transverse rotation, trunk lateral flexion and trunk forward flexion RoM (Major et al., 2014).

**Clinical Relevance**

The upper limb amputation leads to the loss of the voluntary degrees of freedom (DoF). Unfortunately current upper limb prosthesis cannot restore all DoFs. Lack of DOFs, such as controllable wrist rotation or elbow flexion, forces the individual to use compensatory motor strategies to accomplish unilateral functional tasks such as reach and grasp. Clinically, these strategies most prominently involve using the trunk or proximal residual limb to achieve the necessary motion.
Prosthetic users demonstrated a significant increase in shoulder abduction, trunk transverse rotation, trunk lateral flexion, and trunk forward flexion RoM when executing carton pouring, lifting and transferring tasks. Some prosthesis users were unable to routinely execute food cutting and page turning tasks. More experienced prosthetic users showed repeatability of upper body kinematics when conducting tasks. Due to this, transradial prosthesis users may benefit from training that enables optimization of body movement to facilitate execution of ADLs (Major et al., 2014).

Amputees with shoulder disarticulation can benefit from a functional myoelectric prosthesis with a free swinging shoulder joint. MovoShoulder Swing prosthesis decreased swing of the sound arm in shoulder and in elbow joint by 23% and 13%, respectively. It also improved the gait characteristics by reducing the unphysiological loading of the knee joint on amputated side for 12% (Bertels et al., 2012).


Phantom and stump pain

Major Findings

Prosthetic use and phantom limb pain in upper limb amputees:

- The prevalence of phantom pain was 51%, of phantom sensations 76% and of stump pain 49% in subjects with acquired amputation (amputation not due to the congenital malformation).
- Phantom pain was not reported in congenital group.
- Phantom pain did not affect prosthetic usage or functional ability.
- Phantom sensations and stump pain could lead to phantom pain.

Prosthetic use and phantom limb pain in upper limb amputees fitted with myoelectric prosthesis:

- Enhanced use of a myoelectric prosthesis was associated with reduced phantom limb pain and reduced cortical reorganization.
- Phantom limb or stump pain was never given as a reason for discontinuation of prosthetic use.

Average phantom limb pain intensity

First group (MP) had patients with a myoelectric prosthesis who reported extensive wearing time (>8 h/day) and usage (>50 on a visual analogue scale (VAS) ranging from 0–100). The second group (NMP) had either no prosthesis or a cosmetic prosthesis or myoelectric prostheses was poorly used (<8 h/day and/or < 50 VAS). Phantom limb pain intensity measurement was based on the MPI Pain Intensity Scale (range, 0–6). The MP group showed an average phantom limb pain intensity of 0 ± 0, whereas the NMP group reported an intensity of 2.33 ± 1.53 (Lotze et al., 1999).

Clinical Relevance

Phantom and stump pain after upper limb amputation are common problems. The determinants are still poorly understood as well as the impact of the phantom or stump pain experience on the prosthetic use.

Summary

Phantom pain was only reported in the group of patients that acquired amputation during their life and not in patients that were born with upper limb deficiency.

In group with acquired amputation the prevalence of phantom pain was 51%, of phantom sensations 76% and of stump pain 49%. Interestingly, pain in the limb before amputation was experienced by 14% of subjects. Stump pain or pressing the specific place on the stump was triggering phantom pain in 50% and in 28% of amputees respectively (Kooijman et al., 2000).
The phantom pain did not influence the prosthetic use since the prosthesis was used for more than 8 h per day by 72% of amputees (Kooijman et al., 2000) and did not lead to the rejection of the prosthesis (Lotze et al., 1999).

Frequent and extensive use of a myoelectric prosthesis decreased cortical reorganization and decreased phantom limb pain. Amputees that used myoelectric prosthesis more than 8h per day reported reduction in phantom pain over time.


References of summarized studies

<table>
<thead>
<tr>
<th>References of summarized studies</th>
</tr>
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</table>
Fitting a child with myoelectric prosthesis

Major Claims

With Myoelectric prosthesis with "Elektrohand 2000" compared to previous prosthesis (cosmetic, body-powered, myoelectric):

→ All children learned to open myoelectric prosthetic hand
→ 76% of studied children successfully used myoelectric prosthesis
→ Children amputated above elbow wore prosthesis more than 8h per day, while children with amputation below elbow wore prosthesis more than 5h per day
→ Prosthetic training accelerates successful use of the prosthesis
→ Developmental readiness to use myoelectric prosthesis is at 2 years of age

Clinical Relevance

In very young children upper limb deficiency is mainly caused by malformations. Upper limb deficient children can be provided with three types of prosthesis: cosmetic (passive device), body-powered and myoelectric prosthesis (active devices). There still exists a disagreement in the community regarding right age and device to fit a child. Usually, child is initially fitted with a passive, cosmetic prosthesis as soon as being able to sit in stable position. With a passive device, child learns to use both hands, which supports brain development. A next step is transition from passive to an active device. Some experts believe that the child should receive body-powered prosthesis when it is able to stand and grasp an object or when child starts with kindergarten. The progression to the myoelectric prosthesis usually takes place at the age of ten or when the child has fully accepted active prostheses (Shaperman et al., 2003). Other experts believe that children should be fitted as soon as possible with myoelectric prosthesis (Atkins et al., 1996).

Summary

General prosthesis rejection rate of preschool children is very low compared to adults, although being strongly dependent on amputation level. Literature suggests that children amputated above shoulder wore prostheses more than 8h per day on average, while kids with amputation below elbow wore prostheses more than average 5h per day. All children learned how to open myoelectric prosthesis, while 76% successfully used myoelectric prosthesis. This was associated with appropriate prosthetic training. Therefore, infants can profit from myoelectric hand prostheses and myoelectric prosthesis can be fitted as soon as child is 2 years of age (Egermann et al., 2009).
### References of summarized studies

3 Summaries of individual studies

On the following pages you find summaries of studies that researched different myoelectric prostheses. You find detailed information about the study design, methods applied, results and major findings of the study. At the end of each summary you also can read the original study authors’ conclusions.
Luchetti M., Cutti AG, Verni G, Sacchetti R, Rossi N.  
Department of Psychology, University of Bologna, Italy.

Impact of Michelangelo prosthetic hand:  
Findings from a crossover longitudinal study


**Products**

**Michelangelo hand vs Tridigit hands**

**Major Findings**

With Michelangelo compared to conventional myoelectric prosthesis:

- **A higher functionality can be achieved**
  - Score of Box and Block Test increased by 20.8%
  - Score of SHAP increased by 11.4%
  - Time needed to perform Minnesota Manual Dexterity Test decreased by 14.8%

- **ADL execution is easier**
  - Reported by 84% of patients

- **Michelangelo hand is more actively used at home**
  - Lateral grip preferred over opposition grip

- **Gesture and posture is more natural**

**Significant improvement in Box and Block Test**

Box and Blocks is a manual dexterity test where number of blocks transported from one box to another in 60s is assessed. The users were able to transport 5 blocks more on average with Michelangelo hand. Four out of six participants (67%) had a score above minimal clinically relevant detectable change (more than 6.5 blocks were transported with Michelangelo hand in 60s than with conventional myoelectric prosthesis).

**Population**

- **Subjects:** 6 transradial amputees
- **Previous prosthesis:** tridigital myoelectric prosthesis
- **Amputation causes:** trauma
- **Mean age:** 47 yrs (range: 35-65 yrs)
- **Mean time since amputation:** 15 yrs (range: 4.5-48 yrs)
Interventional pre- to post-test design:

The subjects were provided with 5 days of occupational therapy after they have been fitted with Michelangelo.

<table>
<thead>
<tr>
<th>Category</th>
<th>Outcomes</th>
<th>Results for Michelangelo vs Tridigit hands</th>
<th>Sig.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip patterns / force</td>
<td>Activity monitoring data</td>
<td>After 3 months the median number of opening and closing cycles was 32,330. 83% of patients preferred the lateral grip (73% of cycles). After 6 months the median number of opening and closing cycles was 54,012 in total over six months. The lateral grip was preferred for 77% of cycles.</td>
<td>n.a.</td>
</tr>
<tr>
<td>Manual dexterity</td>
<td>Southampton Hand Assessment Procedure (SHAP)</td>
<td>The score for the SHAP was 11.4% higher with Michelangelo than with the conventional prosthesis. A higher score can be interpreted as a higher functionality.</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>Box and Block Test (BBT)</td>
<td>The number of blocks that was carried over a partition was increased by 20.8% suggesting higher hand functionality. 67% of the patients increased the score over the minimal clinically relevant detectable change.</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Manual Dexterity Test (MMDT)</td>
<td>The time for the test was decreased by 14.8% which also can be interpreted as a higher functionality.</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>Disabilities of the Arm, Shoulder, and Hand (DASH)</td>
<td>All patients showed high hand functionality (min DASH row score 26, range 0-100, lower score = higher functionality). No difference was observed between two hands.</td>
<td>0</td>
</tr>
<tr>
<td>Activities of daily living (ADL)</td>
<td>Orthotics and Prosthetics User Survey – Upper Extremity Functional Status (OPUS-UEFS)</td>
<td>84% of the patients reported an easier execution of ADLs.</td>
<td>+</td>
</tr>
<tr>
<td>Satisfaction and Quality of life (QoL)</td>
<td>Hospital Anxiety Depression Scale (HADS)</td>
<td>Despite the fact that questionnaires created to assess satisfaction and quality of life did not show statistical significant difference, interview transcripts emphasised that Michelangelo en-</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>EuroQoL (Health-Related Quality of Life)</td>
<td></td>
<td>0</td>
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<tr>
<td>Category</td>
<td>Outcomes</td>
<td>Results for Michelangelo vs Tridigit hands</td>
<td>Sig.*</td>
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<tr>
<td>Amputee Body Image Scale (ABIS)</td>
<td>enhances functionality and brings more natural gesture and posture.</td>
<td>0</td>
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<tr>
<td>Trinity Amputation and Prosthesis Experience Scales (TAPES) – Upper Limb Version</td>
<td></td>
<td>0</td>
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<tr>
<td>Multidimensional Scale Perceived Social Support (MSPSS)</td>
<td></td>
<td>0</td>
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<tr>
<td>Coping Inventory for Stressful Situations (CISS)</td>
<td></td>
<td>0</td>
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<tr>
<td>Eysenck Personality Questionnaire Revisited – Short Form (SPQR-SF)</td>
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</tbody>
</table>

* no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

**Author's Conclusion**

"Amputation- and prosthetic-related factors, along with psychological factors (e.g., patient coping strategies, attitude, expectations) and social factors (i.e., support of family and friends, reactions of others), need to be screened in the prosthesis fitting process. The present study shows that the M is effective in improving the functional ability and in easing the social interaction of previous active users of a myoelectric prosthesis." (Luchetti et al. 2015)
Ease of Activities of Daily Living with Conventional and Multigrip Myoelectric Hands.

JPO 2015; Vol 27, Num 2, p 46

**Products**
Michelangelo Hand vs previous myoelectric prostheses

**Major Findings**
With Michelangelo Hand compared to previous myoelectric prostheses:

- Perceived difficulty to perform tasks of daily living was decreased by 26%
- Bimanual activities were easier to perform by 24%
- Participants used the prosthesis to actively grasp an object in more bimanual activities

Perceived difficulty of activities of daily living

Perceived difficulty to perform 23 activities of daily living was measured with OPUS-UEFS questionnaire. Total OPUS-UEFS score was 26% higher with Michelangelo prostheses, meaning that tasks were easier to conduct with Michelangelo hand.

**Population**
Subjects: 16 subjects
Previous: 10 Sensor hand speed; 3 Myohand VariPlus Speed; 1 Motion Control Hand, 1 DMC plus Myohand, Elektrogreifer
Amputation causes: 8 traumas, 6 congenital deformities, 1 cancer and 1 sepsis
Mean age: 41 ± 14 years
Mean time since amputation: 12.8 ± 16.1 years

**Study Design**
Interventional, pre- to post-test design:

Previous prosthesis

≥ 4 weeks accommodation

Michelangelo hand

Data collection

Data collection
### Results

<table>
<thead>
<tr>
<th>Category</th>
<th>Outcomes</th>
<th>Results for Michelangelo Hand vs previous myoelectric prostheses</th>
<th>Sig.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activities of daily living</td>
<td>Orthotics &amp; Prosthetics User Survey – Upper Extremity Functional Status (OPUS-UEFS questionnaire)</td>
<td>Perceived difficulty to perform tasks of daily living was decreased: Total OPUS-UEFS score was increased by 26% with Michelangelo prostheses.</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5 activities of daily living (ADLs) were easier to perform with Michelangelo (wash face, put on socks, tie shoe laces, cut meat with knife and fork, carry laundry basket).</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Bimanual activities were easier to perform by 24%.</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Patients used Michelangelo in more activities than the conventional prosthetic hands.</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>The Prosthetic Upper Extremity Functional Index (PUFI)</td>
<td>Patients perceive to perform activities of daily life 15% easier.</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Participants used prosthesis to actively grasp an object in more bimanual activities.</td>
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</tr>
</tbody>
</table>

* no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

### Author's Conclusion

“In conclusion, with the use of the Michelangelo hand, many ADLs were perceived to be easier to perform, resulting in a more active use of the prosthetic hand and a trend to reduce the primarily passive use of the prosthesis. Further research with performance-based outcome measures is encouraged to corroborate these self-reported findings.” (Proebsting et al. 2015)
Comparison of range-of-motion and variability in upper body movements between transradial prosthesis users and able-bodied controls when executing goal-oriented tasks


**Major Findings**

With myoelectric prosthesis users compared to able-bodied controls:

- **Shoulder and trunk movements are common compensatory motions in prosthesis users.**
- **Increased variability in movement suggests that prosthesis users do not stick to a defined motor strategy.**
- **Kinematic repeatability may increase with prosthesis experience.**

**Average range of motion for carton pouring task**

Upper body range of motion (RoM) was analysed on able-bodied controls and myoelectric transradial prosthesis users during execution of carton pouring task (lifting a carton, located at midline of the body, and emptying the liquid contents into a jar on the contralateral side with minimal spilling). Results indicate that prosthesis users demonstrate a significant increase in shoulder abduction, trunk transverse rotation, trunk lateral flexion and trunk forward flexion than able-bodied subjects.

**Population**

| Subjects: | 6 able-bodied controls
| 7 myoelectric transradial prosthesis users |
| Prosthesis: | System Electric Hand, MyoHand VariPlus Speed Hand, Transcarpal Hand, Motion Control Hand, i-Limb Ultra Revolution, i-Limb Ultra and i-Limb Hand |
| Amputation causes: | 4 traumatic, 3 congenital |
| Mean age: | able-bodied individuals - 35 ± 11 year
prosthetic users - 49 ± 18 years |
| Mean time since amputation: | 9.5 ± 11.0 years |
Observational study:

Participants were requested to execute five goal-oriented tasks while seated (carton pouring, page turning, food cutting, lifting and transferring weighted object, lifting and transferring tray). Able-bodied controls and prosthesis users performed these tasks using their non-dominant and prosthetic limb, respectively.

<table>
<thead>
<tr>
<th>Category</th>
<th>Outcomes</th>
<th>Results for myoelectric prosthesis users compared to able-bodied controls:</th>
<th>Sig.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>Goal oriented tasks:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• carton pouring</td>
<td>The majority of prosthesis users were unable to routinely execute food cutting and page turning tasks.</td>
<td>n.a.</td>
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<tr>
<td></td>
<td>• page turning</td>
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<tr>
<td></td>
<td>• food cutting</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• lifting and transferring weighted object</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• lifting and transferring tray</td>
<td></td>
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<tr>
<td></td>
<td>Prosthesis users demonstrated a significant increase in shoulder abduction, trunk transverse rotation, trunk lateral flexion, and trunk forward flexion RoM when executing carton pouring, lifting and transferring tasks.</td>
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<tr>
<td></td>
<td>No difference in shoulder and elbow flexion/extension RoM was observed.</td>
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<td>0</td>
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<tr>
<td></td>
<td>Kinematic variability was high for prosthetic users.</td>
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<tr>
<td></td>
<td>Kinematic repeatability was low for prosthetic users.</td>
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</tbody>
</table>

* no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

Author’s Conclusion

“Transradial prosthesis users utilize shoulder abduction and trunk movement as compensatory motions to execute goal-oriented tasks, and the majority of these motions are accompanied by increased kinematic variability when compared to able-bodied controls. The average repeatability of upper body kinematics was positively associated with prosthesis experience. As these dynamics may be necessary to compensate for the absence of active distal DoFs (degrees of freedom) in the prosthetic arm, transradial prosthesis users may benefit from dedicated training that: 1) encourages optimization of these dynamics to facilitate execution of ADLs, and 2) fosters adaptable but reliable motor strategies.” (Major et al. 2014)
Biomechanical influences of shoulder disarticulation prosthesis during standing and level walking

Prosthetics and Orthotics International 2012; 36(2) 165–172

MovoShoulder Swing with DynamicArm and System Electric Hand vs no prosthesis

Major Findings

MovoShoulder Swing with DynamicArm and System Electric Hand:

- Compensatory movements during walking in shoulder, elbow and knee are reduced when using a free swinging shoulder joint
- Swinging of the sound arm in shoulder joint is 23% reduced
- Swinging of the sound arm in elbow joint is 13% reduced
- Unphysiological loading of the knee joint on amputated side is 12% decreased

Mean range of contralateral shoulder motion during walking with or without prosthesis

The prosthesis (MovoShoulder Swing, DynamicArm and System Electric Hand) reduced the pronounced unphysiological swing of the sound arm (segment angle of sound side decreased from 33° without the prosthesis to 25.5° with prosthesis).

Population

Subjects: 8 patients with unilateral shoulder disarticulation and 6 able-bodied subjects
Amputation causes: 6 traumas, 1 cancer and 1 sepsis
Mean age: 44 ± 13 years
Mean time since amputation: 14 ± 9 years

Study Design

Observational (non-interventional) study:
Aim of this study was to observe the impact of functional arm prosthesis on body posture and gait of shoulder disarticulation patients and compare it with able-bodied individuals.
## Results

<table>
<thead>
<tr>
<th>Category</th>
<th>Outcomes</th>
<th>Results for MovoShoulder Swing with DynamicArm and System Electric Hand vs no prosthesis</th>
<th>Sig.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>Gait analyses (kinematic)</td>
<td>Walking speed between amputees and able bodied participants was similar.</td>
<td>0</td>
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<tr>
<td></td>
<td></td>
<td><strong>Intensive swinging of the sound arm in shoulder and elbow joint is drastically reduced with MovoShoulder Swing and DynamicArm.</strong></td>
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</tr>
<tr>
<td></td>
<td></td>
<td><strong>Shoulder backward rotation is reduced with the use of prosthesis.</strong></td>
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</tr>
<tr>
<td></td>
<td></td>
<td><strong>Unphysiological loading of the knee joint decreases with free swing in the shoulder joint enabled by the prosthesis.</strong></td>
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</tr>
</tbody>
</table>

* no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

### Author's Conclusion

“From the biomechanical point of view, unilateral shoulder disarticulation patients benefit greatly from modern prosthetic systems as described in this paper. This study shows that the patient’s body posture is significantly improved by using a prosthesis. Compensatory movements, such as abnormal swinging of the contralateral arm, are reduced. In addition, unphysiological loading of the knee joint decreases if the prosthetic shoulder joint freely swings in the sagittal plane.” (Bertels et al. 2012)
The Psychosocial and Biomechanical Assessment of Amputees Fitted with Commercial Multi-grip Prosthetic Hands – Case Study: Michelangelo hand


### Products

| Michelangelo hand vs Digital twin hand |

### Major Findings

With Michelangelo hand compared to Digital twin hand:

- Michelangelo hand reduces compensatory movements
- Michelangelo hand gives more natural gesture and posture
- Patient is more satisfied with Michelangelo hand

In disk task participant is moving the disk, positioned in front of the prosthetic hand, over the table. The participant moves disk over the table from the prosthetics hand to the sound hand, then in front of the participant and backwards. Michelangelo hand took same amount of time to perform disk task as sound hand (7s). Digital twin hand needed much more time to complete the same task (11s).

### Population

- Subjects: male, unilateral transradial amputee, dominant side
- Previous: Digital Twin hand (Otto Bock)
- Amputation causes: trauma
- Mean age: 50 years
- Mean time since amputation: 30 years

### Study Design

Case report
## Results

<table>
<thead>
<tr>
<th>Body Function</th>
<th>Activity</th>
<th>Participation</th>
<th>Others</th>
<th>Category</th>
<th>Outcomes</th>
<th>Results for Michelangelo hand vs Digital twin hand</th>
<th>Sig.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>Pain</td>
<td>Grip patterns / force</td>
<td>Manual dexterity</td>
<td>Activities of daily living (ADL)</td>
<td>Satisfaction and Quality of life (QoL)</td>
<td>Training</td>
<td>Technical aspect</td>
</tr>
<tr>
<td></td>
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</tr>
<tr>
<td>Mechanics</td>
<td>Biomechanical analyses</td>
<td>Elbow flexion restriction was present with both prosthesis</td>
<td>Michelangelo hand gave more natural approach to the object. With Digital Twin hand the patient approaches the object in adduction and with a relevant posterior tilting. With the sound and the Michelangelo hand, the patient approaches the object in abduction and almost without relying on scapula tilting.</td>
<td>Michelangelo hand reduced compensatory movements</td>
<td>+</td>
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</tr>
<tr>
<td>Satisfaction</td>
<td>Questionnaire</td>
<td>Patient was more satisfied with Michelangelo than with previous prosthesis</td>
<td>“Results highlighted an increased satisfaction with the new multi-grip hand and, remarkably, the new prosthesis triggered a higher level of embodiment, with a mind changing in the use the previous hand as well. Thanks to pleasant appearance and functional features of Michelangelo, the patient started to assume more natural gestures and postures also with the traditional myoelectric hand, reporting this different way of thinking the prosthesis as “a fundamental step for an amputee”. Regarding the biomechanical assessment, the shoulder biomechanics was positively influenced by the availability of the lateral grip and by the overall hand shape, which allowed the patient to approach cylindrical and coin-shaped objects in a more natural way, limiting the shoulder compensatory movements.” (Cutti et al. 2012)</td>
<td></td>
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</tr>
</tbody>
</table>

* no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

**Author’s Conclusion**

"Results highlighted an increased satisfaction with the new multi-grip hand and, remarkably, the new prosthesis triggered a higher level of embodiment, with a mind changing in the use the previous hand as well. Thanks to pleasant appearance and functional features of Michelangelo, the patient started to assume more natural gestures and postures also with the traditional myoelectric hand, reporting this different way of thinking the prosthesis as “a fundamental step for an amputee”. Regarding the biomechanical assessment, the shoulder biomechanics was positively influenced by the availability of the lateral grip and by the overall hand shape, which allowed the patient to approach cylindrical and coin-shaped objects in a more natural way, limiting the shoulder compensatory movements.” (Cutti et al. 2012)
Mechanical design and performance specifications of anthropomorphic prosthetic hands: A review

Journal of Rehabilitation Research & Development 2011; 10:0188

Products

Michelangelo hand (Otto Bock)
Vincent hand (Vincent Systems)
iLimb hand (Touch Bionics)
iLimb Pulse (Touch Bionics)
Bebionic hand (RSL Steeper)
Bebionic hand v2 (RSL Steeper)

Major Findings

→ Michelangelo hand has the highest grip force in group of multi-articulating hands
→ Michelangelo advantage is in the low number of actuators with transmissions that allow all functional grasping postures

Distribution of hand weight compared with amount of grip force of the hand in grasp configuration

<table>
<thead>
<tr>
<th>Grip Force (N)</th>
<th>Weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>Michelangelo</td>
</tr>
<tr>
<td>100</td>
<td>Michelangelo</td>
</tr>
<tr>
<td>80</td>
<td>BeBionic</td>
</tr>
<tr>
<td>60</td>
<td>BeBionic</td>
</tr>
<tr>
<td>40</td>
<td>Sensor Hand</td>
</tr>
<tr>
<td>20</td>
<td>Sensor Hand</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Population

Subjects: no subject (technical comparison)

Study Design

Compare various prostheses in technical aspects
Comparison of different myoelectric prostheses – Clinical Study Summaries

<table>
<thead>
<tr>
<th>Body Function</th>
<th>Activity</th>
<th>Participation</th>
<th>Others</th>
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</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>Pain</td>
<td>Grip patterns / force</td>
<td>Manual dexterity</td>
</tr>
<tr>
<td><strong>Category</strong></td>
<td><strong>Outcomes</strong></td>
<td><strong>Results for</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Technical aspects</strong></td>
<td>Thumb design and kinematics (authors suggestions)</td>
<td>Weight of the prosthesis (including mechanism, glove, electronics, etc.) should be below 500 g. Michelangelo’s weight is 420g, while all other prosthesis are heavier. Therefore only Michelangelo is fulfilling this criterion.</td>
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<tr>
<td></td>
<td></td>
<td>Simple and robust finger kinematic designs are preferred. All listed prostheses are fulfilling this criterion.</td>
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<td></td>
<td></td>
<td>Powered adduction of the thumb. All listed prostheses are fulfilling this criterion.</td>
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<tr>
<td></td>
<td></td>
<td>The use of brushless motors instead of brushed motors. All listed prostheses are fulfilling this criterion.</td>
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<tr>
<td></td>
<td></td>
<td>A maximum pinch force at the finger tip of 65 N during palmar prehension. Fulfilled only with Michelangelo.</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>230°/s should be achieved by a high-performing prosthesis, while 115°/s is a minimal acceptable speed.</td>
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<tr>
<td></td>
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<td>Compliance in the mechanical design of a prosthetic hand can be achieved in various ways.</td>
<td></td>
</tr>
</tbody>
</table>

* no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

**Author's Conclusion**

“The rules of thumb listed here focus on the mechanical design criteria that the authors are confident in prescribing as a universal opinion, and therefore not all mechanical design criteria discussed earlier in this study are addressed. However, the list provides a thorough foundation upon which mechanical designers of prosthetic hands can reference.” (Belter et al. 2011)

↑ Back to overview table
The i-LIMB hand and the DMC plus hand compared: A case report

Prosthetics and Orthotics International, June 2010; 34(2): 216–220

Products
DMC plus hand vs iLIMB

Major Findings
With DMC plus hand compared to i-LIMB (Touch Bionics):

- Grip strength is higher for DMC plus hand than for i-LIMB hand in all 5 positions measured.
- Index of Functionality (SHAP score) was 30% higher for DMC hand.
- The DCM plus hand offers more power and robustness, when compared to i-LIMB.

Index of Functionality (IoF) for DCM plus hand and i-LIMB

Index of Functionality (IoF) was calculated after Southampton Hand Assessment Procedure (SHAP) test was performed with DCM plus and i-LIMB hand. IoF is a number that provides an overall assessment of hand function.

Population
Subjects: 1 unilateral wrist disarticulation of dominant left side
Previous: Dynamic Mode Control hand (DMC plus hand)
Amputation causes: trauma
Mean age: 45 years
Mean time since amputation: 4 years

Study Design
Case report:

Patient was fitted with DMC plus hand and a passive wrist rotator for two years. Afterwards patient received an i-LIMB hand with a rigid wrist and had 4 weeks of accommodation period. A series of tests were performed with both prosthetic hands.

Reference
van der Niet O, Reinders-Meselink H, Bongers R, Bouwsma H, van der Sluis C
Department of Rehabilitation, University Medical Center Groningen, Groningen
### Results

<table>
<thead>
<tr>
<th>Category</th>
<th>Outcomes</th>
<th>Results for DMC plus hand vs iLIMB</th>
<th>Sig.*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Body Function</strong></td>
<td></td>
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<tr>
<td>Mechanics</td>
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<td></td>
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<tr>
<td>Pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Grip patterns / force</strong></td>
<td>Grip and pinch strength (dynamometer and a pinch meter)</td>
<td>Grip strength is higher for DMC plus hand than for i-LIMB hand in all 5 positions measured.</td>
<td>+</td>
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<tr>
<td></td>
<td></td>
<td>Lateral and tip pinch strength were not applicable for DMC plus hand.</td>
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<td>Strength of tripod pinch was higher with DMC plus hand than with i-LIMB hand.</td>
<td>+</td>
</tr>
<tr>
<td>Southampton Hand</td>
<td>SHAP score with the DMC plus hand was higher than the score with the i-LIMB.</td>
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<tr>
<td>Assessment Procedure</td>
<td></td>
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<tr>
<td>(SHAP)</td>
<td></td>
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<tr>
<td>Visual analogue scale</td>
<td>DMC plus hand was less reliable in holding objects.</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(VAS)</td>
<td>DMC plus hand was valued for its strength.</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DMC hand was valued for its robustness.</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Activities of daily living</td>
<td>Assessment of Capacity for Myoelectric Control (ACMS)</td>
<td>The Capacity of Myoelectric Control is well above average for both devices: 2.6 logits for the i-LIMB hand and 2.47 logits for the DMC plus hand.</td>
<td>0</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Trinity Amputation and Prosthesis Experience Scales (TAPES)</td>
<td>The patient was less satisfied with DMC plus hand.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>Orthotics and Prosthetics Users’ Survey (OPUS)</td>
<td>The OPUS functional status was similar for both prosthesis (29 for the i-LIMB hand and 30 for the DMC plus hand, respectively).</td>
<td>0</td>
</tr>
</tbody>
</table>

* no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

**Author's Conclusion**

“In this case report we could not establish a clear functional advantage of the i-LIMB compared to the DMC-hand. The i-LIMB hand has a higher reliability when holding objects but has less strength and robustness. Thus, dependent on the users’ needs, patients should opt for an i-LIMB hand or a more conventional DMC plus hand. Moreover, future innovations of prosthetic hands should take the limitations of the i-LIMB hand into account.” (van der Niet et al. 2010)
Myoelectric hand prostheses in very young children

International Orthopaedics 2009; 33:1101–1105

Egermann M, Kasten P, Thomsen M
Stiftung Orthopädische Universitätsklinik Heidelberg

Products
Myoelectric prosthesis with “Elektrohand 2000” vs previous prostheses

Major Findings
With Myoelectric prosthesis with “Elektrohand 2000” compared to previous prostheses (cosmetic, body-powered, myoelectric):

- All children learned to open myoelectric prosthetic hand
- 76% of studied children successfully used myoelectric prosthesis
- Children amputated above elbow wore prosthesis more than 8h per day, while children with amputation below elbow wore prosthesis more than 5h per day
- Prosthetic training accelerates successful use of the prosthesis
- Developmental readiness to use myoelectric prosthesis starts with as early as 2 years of age

Mean daily wearing time of myoelectric prosthesis

<table>
<thead>
<tr>
<th>mean daily wearing time (h)</th>
<th>above elbow</th>
<th>below elbow</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<tr>
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<td>9</td>
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</tbody>
</table>

Population
Subjects: 41 children (35 below elbow and 6 above elbow amputees)
Previous: 24 cosmetic, 10 body-powered, 7 myoelectric
Amputation causes: 36 congenital deformities, 5 traumas
Mean age: 3.9 ± 1.1 years
Mean time since amputation: 3.9 ± 1.1 years

Study Design
Retrospective study
This study retrospectively evaluated the fitting of myoelectric prostheses in 41 preschool children with unilateral upper limb amputation.
### Results

<table>
<thead>
<tr>
<th>Category</th>
<th>Outcomes</th>
<th>Results for Myoelectric prosthesis with “Elektrohand 2000” vs previous prostheses</th>
<th>Sig.*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity of daily life</strong></td>
<td>Questionnaire</td>
<td>Children amputated above shoulder wore prostheses more than 8h per day on average, while kids with amputation below elbow wore prostheses more than average 5h per day.</td>
<td>++</td>
</tr>
<tr>
<td></td>
<td>(self-designed)</td>
<td>Children that wore a body-powered active device prior to myoelectric prosthesis show a tendency towards higher wearing time compared to children with a passive device only.</td>
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<tr>
<td></td>
<td></td>
<td>The myoelectric prosthesis was preferentially used for playing and in kindergarten.</td>
<td>+</td>
</tr>
<tr>
<td><strong>Satisfaction</strong></td>
<td>Questionnaire</td>
<td>Myoelectric prosthesis brought more functional benefit to the user.</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>(self-designed)</td>
<td>Users are more satisfied with appearance of myoelectric prosthesis.</td>
<td>+</td>
</tr>
<tr>
<td><strong>Technical aspects</strong></td>
<td>Questionnaire</td>
<td>Myoelectric prostheses were more sustainable for breakdown than body powered prostheses.</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>(self-designed)</td>
<td>Myoelectric prostheses were heavy.</td>
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<td></td>
<td></td>
<td>Life span of battery in myoelectric prosthesis was too short.</td>
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</table>

* no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

### Author's Conclusion

“The prosthesis was used for an average time of 5.8 hours per day. The level of amputation was found to influence the acceptance rate. Furthermore, prosthetic use training by an occupational therapist is related to successful use of the prosthesis. The general drop-out rate in preschool children is very low compared to adults. Therefore, infants can profit from myoelectric hand prostheses. Since a correct indication and an intense training program significantly influence the acceptance rate, introduction of myoelectric prostheses to preschool children should take place at specialised centres with an interdisciplinary team.” (Egermann et al. 2009)
Objectifying the Functional Advantages of Prosthetic Wrist Flexion

Journal of Prosthetics & Orthotics 2009; Vol 21, Num 2

Bertels T, Schmalz T, Ludwigs E
Otto Bock HealthCare GmbH, Goettingen

Wrist flexion of 40° is preferred by 50% of the patients.
Active wrist reduces compensatory movements of shoulder

Subjects: 6 transradial amputees
Previous: not specified
Amputation causes: 3 traumas and 3 congenital deficiencies
Mean age: 39 ± 21 years
Mean time since amputation: 23 ± 15 years

Study Design
Pilot study
Study was designed to compare benefits of wrist motion at 20° and 40° in flexion and extension with the locked wrist (0° in flexion and extension).

Mechanics
Motion analyses of wrist, elbow and shoulder
The compensatory movements with wrist flexion were drastically reduced while performing ADL.
With wrist flexion, anteverision (being tilted further forward than normal) of a shoulder was decreased for 35°.
With wrist flexion, shoulder tilting is reduced by

Results for Transcarpal-Hand with and without Transcarpal Myowrist

<table>
<thead>
<tr>
<th>Category</th>
<th>Outcomes</th>
<th>Results</th>
<th>Sig.*</th>
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</thead>
<tbody>
<tr>
<td>Mechanics</td>
<td>Motion analyses of wrist, elbow and shoulder</td>
<td>The compensatory movements with wrist flexion were drastically reduced while performing ADL.</td>
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<td></td>
<td>With wrist flexion, anteverision (being tilted further forward than normal) of a shoulder was decreased for 35°.</td>
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<tr>
<td></td>
<td></td>
<td>With wrist flexion, shoulder tilting is reduced by</td>
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</tbody>
</table>
### Outcome: Wrist Flexion

<table>
<thead>
<tr>
<th>Category</th>
<th>Outcomes</th>
<th>Results for Transcarpal-Hand with and without Transcarpal Myowrist</th>
<th>Sig.*</th>
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<tbody>
<tr>
<td></td>
<td>7°. Wrist flexion of 40° is preferred by 50% of the patients.</td>
<td>+</td>
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</tbody>
</table>

* no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

### Author's Conclusion

“In the present pilot study, motion patterns typically performed in the patients’ daily life were selected. The results of motion analysis show that compensatory movements may be reduced by wrist flexion in most of the cases. This is noted considerably by kinematic characteristics of the shoulder joint on the prosthetic side. Even if only slight differences of few degrees were measured, the patients perceived an optimization of the motion pattern. Reduced compensatory movements support more physiological loading of the unaffected joints of the locomotor system. The more natural subjective impression is an important psychological aspect for the prosthetic user.” (Bertels et al. 2009)

[Back to overview table]
Lotze M, Grodd W, Birbaumer N, Erb M, Huse E and Flor H
Department of Neuroradiology, University of Tübingen, Germany

Does use of a myoelectric prosthesis prevent cortical reorganization and phantom limb pain?
Nature Neuroscience, volume 2 no 6, June 1999

Myoelectric prosthesis, cosmetic prosthesis

Prosthetic use and phantom limb pain in upper limb amputees:

Enhanced use of a myoelectric prosthesis was associated with reduced phantom limb pain and reduced cortical reorganization. Phantom limb or stump pain was never given as a reason for discontinuation of prosthetic use.

Average phantom limb pain intensity

1. First group (MP) had patients with a myoelectric prosthesis who reported extensive wearing time (>8 h/day) and usage (>50 on a visual analogue scale (VAS) ranging from 0–100). The second group (NMP) had either no prosthesis or a cosmetic prosthesis or myoelectric prostheses was poorly used (<8 h/day and/or < 50 VAS). Phantom limb pain intensity measurement was based on the MPI Pain Intensity Scale (range, 0–6). The MP group showed an average phantom limb pain intensity of 0 ± 0.8 (no pain), whereas the NMP group reported an intensity of 2.33 ± 1.53.

Population

Subjects: 9 upper limb amputees; 10 control, healthy participants
Previous: 2 myoelectric prosthesis, 3 cosmetic prosthesis, 4 no prosthesis
Amputation causes: not listed
Mean age: 49 ± 18 years
Mean time since amputation: 22 ± 19 years

Study Design

Observational study

Nine unilateral upper-limb amputees and 10 control participants were examined with functional magnetic resonance imaging (fMRI) of the brain while they moved the lip. Location and amount of cortex devoted to each part of the body is known and described. Cortical reorganization was assessed by comparing the location and the extent of the cortical representation during the lip movements in comparison to hand location in healthy and upper limb amputated participants.
## Results

<table>
<thead>
<tr>
<th>Category</th>
<th>Outcomes</th>
<th>Results for amputees with and without phantom pain</th>
<th>Sig.*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanics - Pain</td>
<td>functional Magnetic Resonance Imaging (fMRI) of brain</td>
<td>In amputees with phantom limb pain, cortical area of activation during lip movement was displaced towards the hand area (by 10.67 ± 7.33 mm in somatosensory cortex and 5.84 ± 3.57 mm in motor cortex). In pain free amputees, area of activation during lip movement was symmetrical.</td>
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<tr>
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<td>Cortical area of activation during lip movement was more symmetrical in group of extensive prosthetic users (myoelectric prosthesis used &gt;8 h/day - MP group) than in the group of amputees that poorly used their prostheses (no prosthesis or cosmetic prosthesis or myoelectric prostheses used &lt;8 h/day – NMP group)</td>
<td>++</td>
</tr>
<tr>
<td>Pain Intensity Scale (range, 0–6)</td>
<td>The MP group showed an average phantom limb pain intensity of 0 ± 0, whereas the NMP group reported an intensity of 2.33 ± 1.53.</td>
<td>Reduction in phantom limb pain over time was significantly positively correlated with extensive myoelectric prosthesis use.</td>
<td>++</td>
</tr>
<tr>
<td>Satisfaction</td>
<td>Satisfaction with the prosthesis</td>
<td>Reasons given for discontinuation (typically in the first months after amputation) were preference for the intact arm and/or impracticability of the prosthesis, but never phantom limb or stump pain.</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

* no difference (0), positive trend (+), negative trend (−), significant (++/−−), not applicable (n.a.)

### Author’s Conclusion

“This study showed that frequent and extensive use of a myoelectric prosthesis is correlated negatively with cortical reorganization and phantom limb pain and positively with the reduction in phantom limb pain over time. This suggests that the ongoing stimulation, muscular training of the stump and visual feedback from the prosthesis might have a beneficial effect on both cortical reorganization and phantom limb pain. The converse that increased phantom limb pain might have motivated patients to decrease prosthesis use, is unlikely because no patient reported increased phantom limb pain with prosthesis use or gave stump or phantom limb pain as reason for discontinuing prosthesis use. Our data are in accordance with animal experiments suggesting that behaviourally relevant tactile stimulation expands the cortical representation of the stimulated body region. Our data strongly suggest that extended use of a myoelectric prosthesis might reduce both cortical reorganization and phantom limb pain, a still relatively treatment-resistant disorder.” (Lotzke et al. 1999)

[Back to overview table]