For the model using 50 mg of losartan as the target dose, 33.3% of candesartan patients received 76% or more of the target dose vs 78.0% of losartan patients. For the model using 150 mg of losartan as the target dose, 33.3% of candesartan patients received 25% or more of the target dose vs 0.2% of losartan patients. The actual mean (SD) dose of candesartan was 18 (11) mg (56% [36%] of the target dose of 32 mg) and of losartan, 53 (26) mg (106% [52%] of the target dose of 50 mg and 35% [17%] of the target dose of 150 mg). Candesartan was associated with less mortality than losartan in all models, with adjustment for dose with a target of 50 mg or 150 mg, and in multivariate models with and without propensity scores. There was no interaction with dose, regardless of whether the target losartan dose was 50 mg or 150 mg. This was a retrospective analysis and not a trial, but we agree that patients were likely titrated toward 50 mg prior to the HEAAL study and 150 mg after, if it was tolerated. Our findings should be confirmed in other studies, but the suggestion that candesartan is associated with lower mortality than losartan in HF remains.

Lars H. Lund, MD, PhD
lars.lund@alumni.duke.edu
Department of Cardiology
Karolinska University Hospital
Stockholm, Sweden

Lina Benson, MSc
Department of Clinical Science and Education
Karolinska Institutet
Stockholm

Maria Eklind-Cervenka, MD
Department of Cardiology
South Hospital
Stockholm

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RESEARCH LETTER

Real-Time Myoelectric Control of Knee and Ankle Motions for Transfemoral Amputees

To the Editor: We recently investigated real-time neural control of artificial arms using targeted muscle reinnervation and pattern recognition algorithms.[1] However, lower limb amputees outnumber upper limb amputees.[2] There has been increased interest in neurally controlled powered lower limb prosthetics because they can restore activities that require joint power to be generated.[3-5] We have extended our research to lower limb amputees.

Methods. Four transfemoral amputee participants (3 men, 1 woman; mean [SD] age, 50 [9] years; mean [SD] time since amputation, 18 [16.2] years) and 4 intact-limb control participants (2 men, 2 women; mean [SD] age, 29 [2.4] years) were recruited between September 2009 and January 2011 at the Rehabilitation Institute of Chicago. The Northwestern University institutional review board approved the study, and written informed consent was obtained from all participants.

Individuals were seated with bipolar electrodes placed on the skin's surface over 9 muscles: semitendinosus, sartorius, tensor fasciae latae, adductor magnus, gracilis, vastus medialis, rectus femoris, vastus lateralis, and long head of the biceps femoris. Muscle sites were localized based on a combination of normal anatomical locations and palpation[6] and confirmed by viewing electromyographic (EMG) signals during test contractions (see interactive illustration of lower extremity neuromuscular anatomy, available at http://www.jama.com). Software[1] instructed participants to complete the following motions: knee flexion and extension, plantar flexion and dorsiflexion, internal and external tibial rotation, internal and external femoral rotation, and relaxation. Twelve seconds of EMG data were collected for each motion from which the computer learned the participants' EMG signal patterns using pattern recognition algorithms.[1] Twelve additional seconds of EMG data were collected for each motion to compute classification accuracy (the percentage of motions correctly predicted by the algorithm). Participants completed virtual environment real-time tests that required them to replicate motions displayed on the computer screen. Trials were successfully completed when the user moved the virtual limb through the complete range of motion that required a minimum of 1 second and were terminated after 15 seconds. There were 2 tests: one completed with a 2–degrees of freedom (DOF) virtual prosthesis and the other a 4-DOF virtual prosthesis (see video of virtual prosthesis testing, available at http://www.jama.com). Motions were repeated 9 times during 2-DOF tests but only 3 times during 4-DOF tests because more motions were tested.

Performance metrics included classification accuracy, motion completion time, and motion completion percentage.[1] Motion completion time is the time taken from the start of

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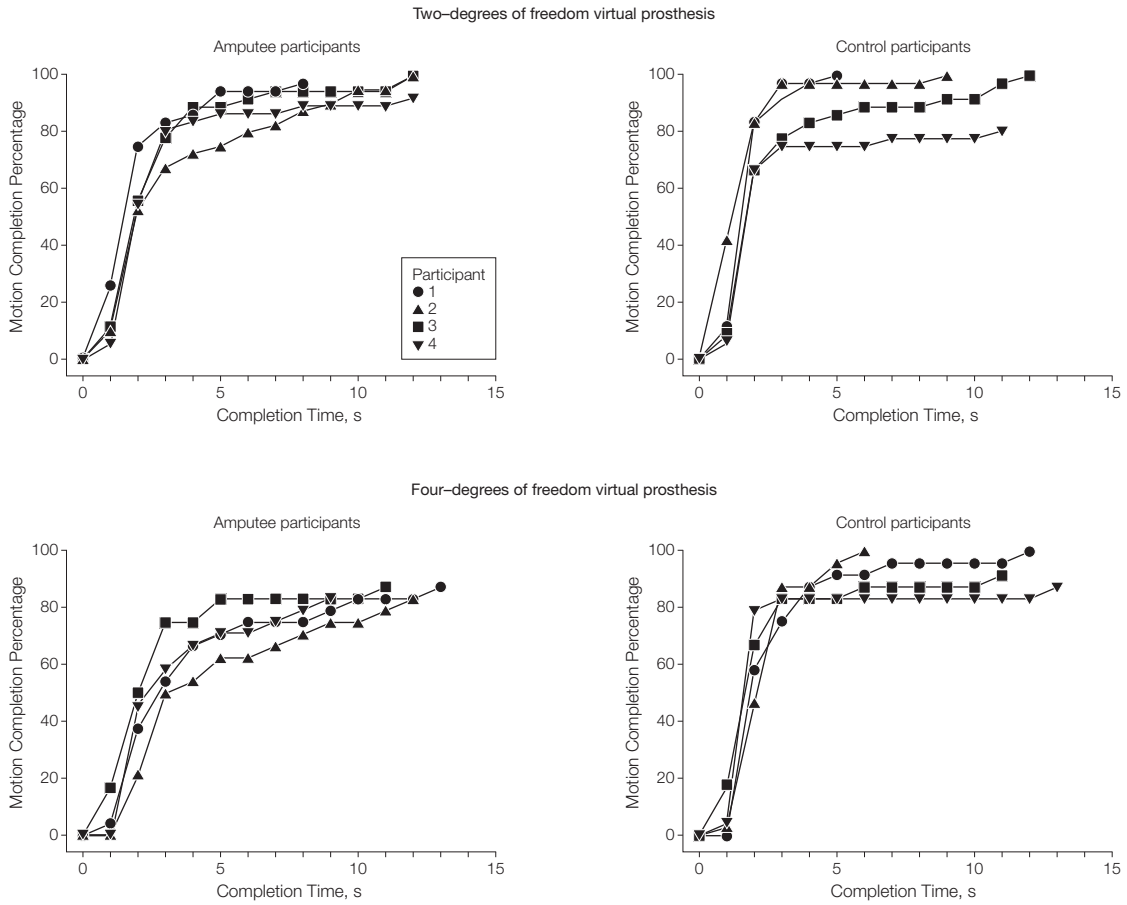
the trial until the virtual limb moved through the complete range of motion. Motion completion percentage is the number of successfully completed motions divided by the total number of trials.

Results. All participants could control both the knee and ankle in the presence of real-time feedback during the 2-DOF test (FIGURE). All participants also demonstrated 4-DOF control, but with lower performance met-

Figure. Cumulative Motion Completion Percentages



Results from controlling 2 degrees of freedom (knee flexion/extension and ankle plantar flexion/dorsiflexion) and 4 degrees of freedom (knee flexion/extension, femoral rotation, ankle plantar flexion/dorsiflexion, and tibial rotation). Trials were terminated after 15 seconds if unsuccessful. See video of virtual prosthesis testing, available at http://www.jama.com.

Table. Performance Metrics for Virtual Prosthesis Testing

	Amputee Participants					Control Participants				
	1	2	3	4	Mean (SD)	1	2	3	4	Mean (SD)
	Two Degrees of Freedom: Knee F/E and Ankle DF/PF[a]									
Classification accuracy, %										
Overall	97.0	92.0	89.0	86.0	91.0 (4.7)	94.0	92.0	86.0	84.0	89.0 (4.8)
Hip/knee	93.5	93.5	86.5	93.5	91.8 (3.5)	95.0	100.0	100.0	99.5	98.6 (2.4)
Ankle	98.5	85.5	85.5	70.5	85.0 (11.4)	96.0	80.0	70.5	50.5	74.3 (19.0)
Motion completion time, s[b]										
Overall	1.84	3.48	2.58	2.22	2.53 (0.70)	1.59	1.61	2.73	1.85	1.94 (0.54)
Hip/knee	1.77	1.68	2.10	1.50	1.76 (0.25)	1.54	1.13	1.29	1.36	1.33 (0.17)
Ankle	1.91	5.28	3.06	3.07	3.33 (1.41)	1.63	2.09	4.17	2.65	2.63 (1.10)
Motion completion percentage, %										
Overall	97.2	100.0	100.0	91.7	97.2 (3.9)	100.0	100.0	100.0	80.6	95.1 (9.7)
Hip/knee	100.0	100.0	100.0	100.0	100.0 (0.0)	100.0	100.0	100.0	100.0	100.0 (0.0)
Ankle	94.4	100.0	100.0	83.3	94.4 (7.9)	100.0	100.0	100.0	61.1	90.3 (19.4)

(continued)

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Table. Performance Metrics for Virtual Prosthesis Testing (continued)

	Amputee Participants					Control Participants				
	1	2	3	4	Mean (SD)	1	2	3	4	Mean (SD)
Four Degrees of Freedom: Knee F/E, Femoral Rotation, Ankle DF/PF, and I/E Tibial Rotation[c]										
Classification accuracy, %										
Overall	90.0	88.0	83.0	86.0	86.8 (3.0)	83.0	92.0	88.0	92.0	88.8 (4.3)
Hip/knee	76.5	90.5	85.0	92.3	86.1 (7.1)	94.3	99.8	99.0	99.0	98.0 (2.5)
Ankle	94.8	90.8	76.5	77.3	84.8 (9.3)	87.8	84.4	76.4	82.5	82.8 (4.8)
Motion completion time, s[b]										
Overall	3.45	3.96	2.36	2.83	3.15 (0.70)	2.65	2.32	2.18	1.89	2.26 (0.32)
Hip/knee	2.97	4.15	1.69	2.64	2.86 (1.02)	1.56	2.09	1.68	1.41	1.69 (0.29)
Ankle	3.97	3.73	2.97	3.11	3.44 (0.48)	3.73	2.55	2.77	2.52	2.89 (0.57)
Motion completion percentage, %										
Overall	87.5	83.3	87.5	83.3	85.4 (2.4)	100.0	100.0	91.7	87.5	94.8 (6.3)
Hip/knee	91.7	91.7	83.3	100.0	91.7 (6.8)	100.0	100.0	100.0	100.0	100.0 (0.0)
Ankle	83.3	75.0	91.7	66.7	79.2 (10.8)	100.0	100.0	83.3	75.0	89.6 (12.5)

Abbreviations: DF/PF, dorsiflexion/plantar flexion; F/E, flexion/extension; I/E, internal/external.
[a] Nine repetitions of each motion.
[b] Trials were terminated after 15 seconds if unsuccessful.
[c] Three repetitions of each motion.

rics, particularly for overall motion completion percentage for amputees (TABLE).

Comment. Although neural control of a single DOF at the knee during non–weight-bearing situations has been shown previously,[3] this is to our knowledge the first demonstration of neural control of a knee and ankle. Real-time ankle control was unexpected using only EMG signals measured from thigh muscles. These results suggest that targeted muscle reinnervation may not be required to achieve non–weight-bearing control of sagittal plane knee and ankle movements. This is a preliminary study with few participants, and testing was completed in a virtual environment. We are currently modifying powered knee and ankle prostheses[3,4] to implement our neural control algorithms. Whether these findings will apply when tested on physical prostheses remains to be tested.

Levi J. Hargrove, PhD
l-hargrove@northwestern.edu
Ann M. Simon, PhD
Robert D. Lipschutz, CP
Suzanne B. Finucane, MS, PTA
Todd A. Kuiken, MD, PhD
Center for Bionic Medicine
Rehabilitation Institute of Chicago
Chicago, Illinois

Author Contributions: Dr Hargrove had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Study concept and design: Hargrove, Simon, Lipschutz, Finucane, Kuiken.
Acquisition of data: Hargrove, Simon, Lipschutz, Finucane.
Analysis and interpretation of data: Hargrove, Simon.
Drafting of the manuscript: Hargrove, Simon.
Critical revision of the manuscript for important intellectual content: Lipschutz, Finucane, Kuiken.
Statistical analysis: Hargrove.
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Online-Only Material: The video and interactive feature are available at http://www.jama.com.

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CORRECTION

Table Error: In the Commentary entitled "Terminology for Preparations of Botulinum Neurotoxins: What a Difference a Name Makes," published in the January 5, 2011, issue of *JAMA* (2011;305[1]:89-90), in the table, in column 4, under "AbobotulinumtoxinA," the second to last line of the table should be "2°C-8°C" instead of "Room temperature." This article has been corrected online.

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