

AWARD NUMBER: W81XWH-20-1-0884

TITLE: Multiaxis Prosthesis Control Through an Osseointegrated Neural Interface

PRINCIPAL INVESTIGATOR: Peter G. Adamczyk, Ph.D.

CONTRACTING ORGANIZATION: University of Wisconsin System, Madison, WI

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PREPARED FOR: U.S. Army Medical Research and Development Command
Fort Detrick, Maryland 21702-5012

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14. ABSTRACT Persons with lower-limb amputation lose both the structure of a limb and control over its functions. This research will contribute to solving problems of prosthesis function, attachment, and sensorimotor interfacing. We will refine a two-axis prosthetic ankle to improve balance and reduce discomfort by adapting to terrain and different movement behaviors. We will test this prosthesis to determine its benefits in activities including sloped walking and walking on curved paths or turns. We will also advance the science of osseointegration and neural interfaces using sheep as a model of human amputation, implanting a mechanical anchor in the bone and a two-way neural recording and stimulation system with nerves in both muscle and bone. The mechanical anchor will support the prosthesis, whereas the neural interface will transfer neural signals from the sheep to control the prosthesis and from the prosthesis to give sensation to the sheep. We will test the ability of the sheep to control the prosthesis and to sense ground forces using this two-way neural interface.					
15. SUBJECT TERMS None listed.					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
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1. INTRODUCTION: *Narrative that briefly (one paragraph) describes the subject, purpose and scope of the research.*

This research addresses lower-limb prosthesis technology, osseointegration of a prosthesis with the skeleton, and neural interfaces for control of prostheses and restoration of sensation. First, the research will advance the development of a two-axis prosthetic ankle for terrain and activity adaptation. Development will include human testing and multiple revisions. Second, the research will adapt osseointegration technology and techniques (bone-implanted, percutaneous prosthesis attachment) to a sheep model of amputation, adding special abutment features for in-bone implantation of electrodes for a neural interface. Third, the research will test bidirectional neural interfacing, recording signals from residual limb muscles to command prosthesis movement and delivering information from external force measurements as neural stimulation to peripheral nerves implanted in the bone canal. Three sheep will be tested for their ability to learn to control the prosthesis and respond to external forces indicated through stimulation.

2. KEYWORDS: *Provide a brief list of keywords (limit to 20 words).*

Limb loss; mobility; prosthesis; multiaxis; sheep model; amputation; neural interface; bidirectional; osseointegration

3. **ACCOMPLISHMENTS:** *The PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency grants official whenever there are significant changes in the project or its direction.*

What were the major goals of the project?

List the major goals of the project as stated in the approved SOW. If the application listed milestones/target dates for important activities or phases of the project, identify these dates and show actual completion dates or the percentage of completion.

Specific Aims:

- (1) Refine a Two-Axis ‘Daptable Ankle (TADA) prosthesis and test its effects on human biomechanics without neural control.
- (2) Develop a Sheep TADA (STADA) prosthesis and integrate with bidirectional neural interface.
- (3) Evaluate the STADA prosthesis controlled by an ONI in a chronic sheep model of amputation with bidirectional osseointegrated neural interface.

Abbreviations: UW= University of Wisconsin - Madison; UU= University of Utah; DU= Duke University; TADA= Two-Axis ‘Daptable Ankle (prosthesis); STADA= Sheep TADA; EMG= electromyography

Aim/Task	Timeline (Months)	Progress (%)
Specific Aim 1: Refine the TADA prosthetic ankle and test its effects on human biomechanics without neural control.		
Major Task 1: Refine and Test TADA v2 and v3	1-30	60%
Specific Aim 2: Develop a Sheep TADA (STADA) prosthesis and integrate with bidirectional neural interface.		
Major Task 2: Sheep TADA (STADA) prosthesis with bidirectional communication with neural interface.	18-30	50%
Specific Aim 3: Evaluation of the TADA prosthetic controlled by an ONI in a chronic ovine model.		
Major Task 3: Closed loop control of a TADA prosthesis	18-48	10%
Specific Aim 3: Evaluation of the TADA prosthetic controlled by an ONI in a chronic ovine model.		

What was accomplished under these goals?

For this reporting period describe: 1) major activities; 2) specific objectives; 3) significant results or key outcomes, including major findings, developments, or conclusions (both positive and negative); and/or 4) other achievements. Include a discussion of stated goals not met. Description shall include pertinent data and graphs in sufficient detail to explain any significant results achieved. A succinct description of the methodology used shall be provided. As the project progresses to completion, the emphasis in reporting in this section should shift from reporting activities to reporting accomplishments.

Aim/Task	Timeline (Months)	Progress (%)
Specific Aim 1: Refine the TADA prosthetic ankle and test its effects on human biomechanics without neural control.		
Major Task 1: Refine and Test TADA v2 and v3		
Subtask 1: Test variations of mechanism geometry, materials, and sizing. Codify design rules. Select an improved design.	1-6	90%
Subtask 2: Upgrade motors and transmission. Optimize sensors for control and evaluation. Select new design.	1-6	100%
Subtask 3: Build TADA with a protective housing and embedded electronics. Assemble with foot prosthesis. Tune control algorithms.	6-12	90%
Subtask 4: Test TADA revision: mechanical tests, pilot tests of walking in <u>2 participants</u> .	9-18	70%
<u>Repeat Subtasks 1-4 to finalize design of TADA v3.</u> <u>2 more participants</u>	15-24	50%
Subtask 5: Test TADA performance and human biomechanics in uneven locomotion: speeds, ramps, side slopes, curves. <u>Test 10 human subjects</u>	18-27	40%
Subtask 6: Dissemination Publish design paper (mechanism considerations). Publish human testing paper (nonlevel terrain with TADA).	21-30	25%
Milestone(s)		
HRPO/ACURO Approval	5	100%
TADA v3 suitable for scaled-up human trial.	21	40%
Design principles for TADA mechanism of any load capacity.	21	50%
Manuscript on design principles.	30	50%
Manuscript on human trial results.	36	50%
<p>Comments:</p> <p>Task 1 Subtasks 1-3: TADA v2 was made functional and programmed to execute patterns of movement during specific tests in walking.</p> <p>Subtasks 4-5: TADA v2 was used for testing in walking tests in unimpaired persons using a prosthesis simulator boot, to test its durability and determine pilot results on its biomechanical effects. Two tests were performed using TADA v2. First, 3 subjects performed level hallway walking, while the TADA moved through a programmed sequence of ankle angles and the incorporated pylon load cell measured frontal and sagittal moments at the proximal end of the prosthesis. Second, 5 subjects performed walking in clockwise and counterclockwise circles of 1m and 2 m radius, with the TADA in three configurations (inversion, neutral, and eversion). Results of these tests are shown in the Figures below.</p> <p>We also designed the concept and produced several subprototypes of TADA v3, which is reduced in size and weight and has intermediate speed compared to TADA v1 and v2. TADA v3 parts went out for machining quotes just at/near the end of the report year.</p> <p>Subtask 6: We performed early stages of dissemination through conference posters. Two manuscripts were drafted by Kieran Nichols based on his dissertation chapters, and we will continue polishing those.</p>		

Specific Aim 2: Develop a Sheep TADA (STADA) prosthesis and integrate with bidirectional neural interface.		
Major Task 2: Sheep TADA (STADA) prosthesis with bidirectional communication with neural interface.		
Subtask 1: Manufacture of osseointegrated implants	18-24	100%
Subtask 2: Design and manufacture of Sheep TADA	18-24	90%
Subtask 3: Design and manufacture uninstrumented passive prostheses	18-24	100%
Subtask 4: Ovine TADA bench testing	18-24	80%
Subtask 5: Programming communications of STADA with implantable ONI.	21-30	5%
Subtask 6: Design and manufacture instrumented passive prostheses	21-30	100%
Milestone(s) Achieved:		
Production of preliminary ovine TADA schematics	18-20	100%
Production of the first ovine TADA prototype	24	100%
Full bidirectional integration (sensory and control)	30	5%

Comments:

Task 2 Subtasks 1 and 3: Implants and passive prostheses for the sheep are complete.

Task 2 Subtasks 2 and 4: First walkable version of the Sheep TADA (STADA), with two “toes” representing the sides of an ovine hoof, has been built and walked on by the sheep. The device survived that testing, so a next-generation is under a continuing design process, to achieve the robustness needed for longer testing. Improvements include: electronic force sensors to detect and coarsely localize ground contact at four locations; urethane tread/coating for traction and robustness; embedded electronics with wires to a control harness at the chest; limits to the movement for safety. These improvements have been gradual and are continuing into year 4.

Task 2 Subtask 5: Programming of STADA with ONI: as with the prior year, there is no practical progress yet given the challenges with the implantation. We put a little effort into recording EMG signals from the human body to control it, but that has taken a back seat to the other testing and redesign work.

Specific Aim 3: Evaluation of the TADA prosthetic controlled by an ONI in a chronic ovine model.		
Major Task 3: Closed loop control of a TADA prosthesis		
Subtask 1: Pre-surgical behavioral assessment in sheep - free ambulation, standing, structured tests (3 sheep)	18-24	0%
Subtask 2: Surgical procedure (3 sheep)	18-24	75%
Subtask 3: Open loop electrophysiology (3 sheep)	19-45	20%
Subtask 4: Closed loop TADA control (3 sheep)	24-45	0%
Subtask 5: Behavioral assessment during free ambulation (3 sheep)	18-24	0%
Milestone(s) Achieved:		
First surgery	18-24	100%
First implementation of the STADA prosthesis	24	60%
Testing complete	45	0%
Paper on ovine ONI	48	0%
Paper on closed-loop control of STADA in sheep	48	0%

Comments:

Task 3 Subtask 1: as last year, behavioral testing has taken a back seat to the more urgent tasks related to implants and surgery.

Subtask 2: Two additional surgeries have been performed. The first of these (May 2023) resulted in successful initial testing of the implanted neural interface, in the sense that the osseointegrated abutment was stable and all the signals were available and recorded. Unfortunately, the animal ended up with an infection that did not respond to treatment and had to be euthanized. Still, this was more successful than the prior case. The second surgery was in August, and the sheep was again successful in weight bearing and generating initial electrophysiological signals. Recovery was ongoing at the time of the report cycle end.

Subtask 3: As described in Subtask 3, portions of the initial electrophysiological testing have proved successful when implants were active in the recovering sheep. This included the ability to stimulate a different electrode and read the induced signal at a more proximal electrode on the same nerve.

Subtasks 4-5: future, no animals ready yet.

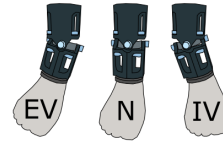
Figure 1: Results of circle walking with TADA v2 (from Roembke et al ASB 2023 poster).



n=5 healthy young adults
12 trials of 3 circles each:

Angles

- 10° everted (EV)
- Neutral (N)
- 10° inverted (IV)



Circle Radius

- 1 meter
- 2 meter

Direction

- Clockwise (CW)
- Counterclockwise (CCW)

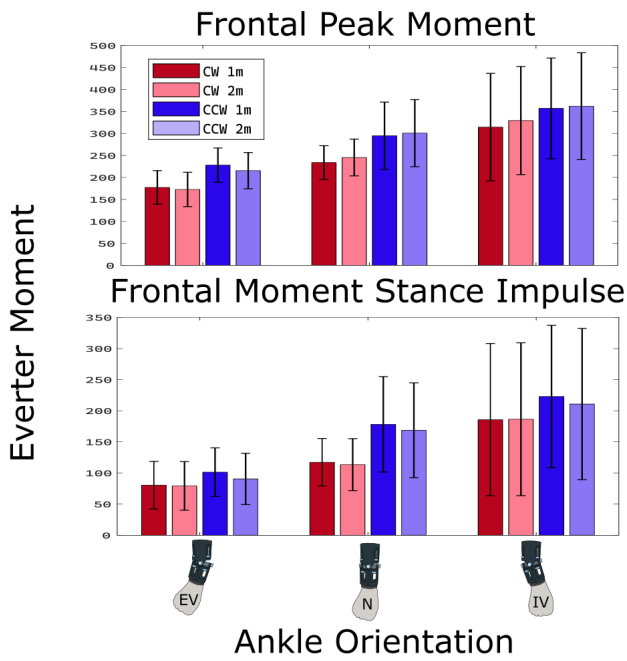
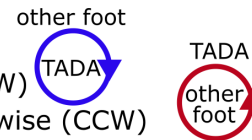
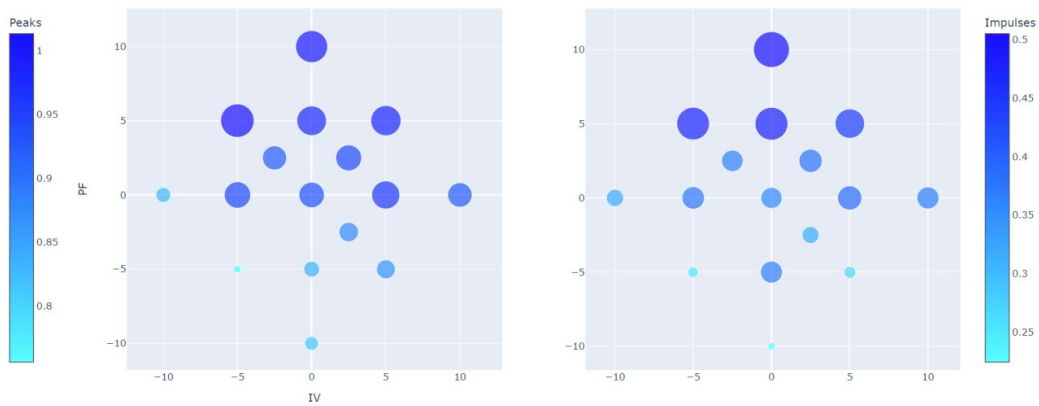


Figure 2: Results from hallway walking tests in TADA v2 (Nichols 2023 ISB and dissertation). The participant walked back and forth in a long hallway while the TADA moved to different ankle angles during swing phases. Each orientation was held for 6-10 steps and followed by a return to neutral for 5 steps. The integrated pylon load cell recorded sagittal (top) and frontal (bottom) moment at the top of the prosthesis, reported here as Peak Moment (left) and Impulse of Moment (right). In each plot, the axes indicate Inversion (IV) and Plantarflexion (PF) angles, which can be positive or negative; the TADA can move to arbitrary combinations of both, indicated by the dots. The size and color of each dot indicates the value of the moment (peak or impulse) in that configuration. Sagittal moment increased with plantarflexion posture and, to a lesser extent, with inversion; Frontal moment increased with inversion angle and somewhat with plantarflexion. The last image shows eversion and inversion postures with the path of the ground reaction force, as a partial explanation for the frontal moment results. These may be different when tested with amputees, as the simulator/bypass orthosis does change the mechanics.

PF vs IV, with Sagittal Moment Peaks(left) and Impulses (right) as marker color and size



PF vs IV, with Frontal Moment Peaks(left) and Impulses (right) as marker color and size

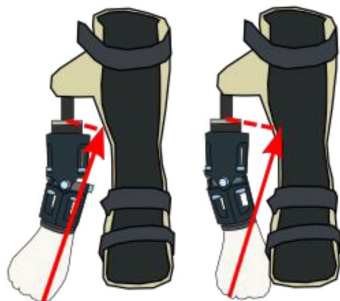
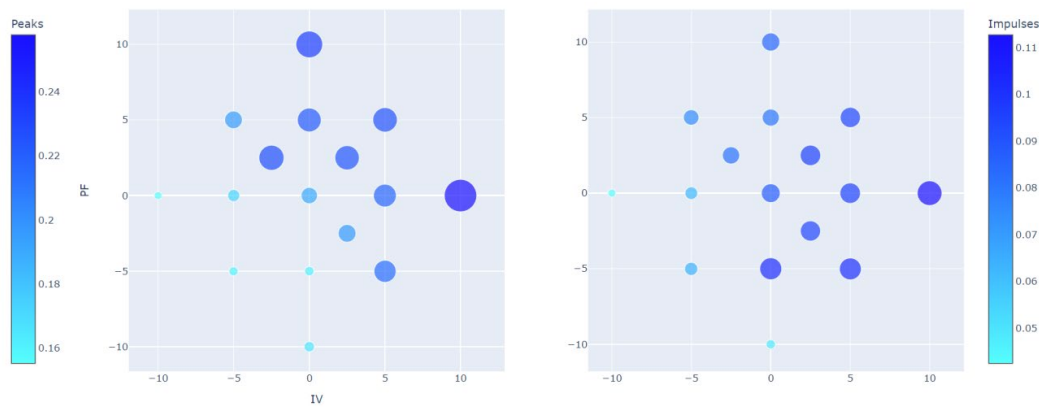
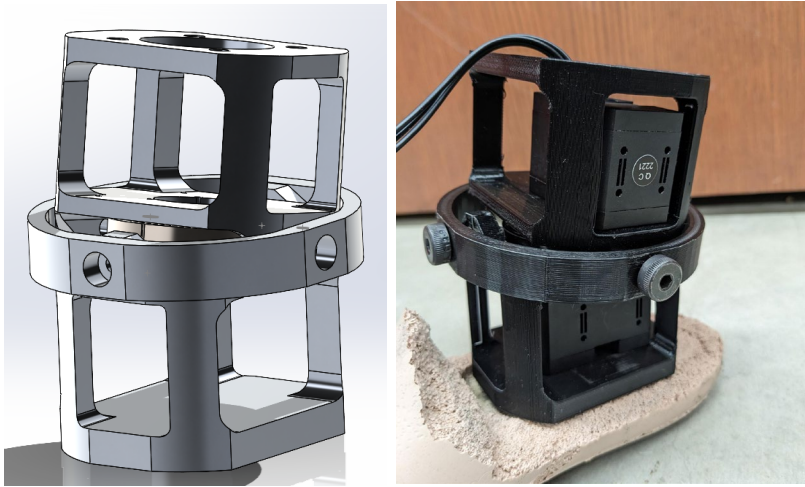


Figure 3: Design and form-and-function prototype (3D printed plastic) of TADA v3. The motors have been reduced in size and weight (and speed) relative to TADA v2, and use a simpler, lighter and more compact control hardware system. The housings will go back to aluminum construction (rather than carbon-fiber-reinforced 3D-printed parts in v2, which proved too anisotropic in strength). The wedge cams that operate the system (hidden by other parts) will be upgraded from aluminum to steel; the steel is heavy, but it will be more suitable for high contact stress between parts, and hopefully will not require lubrication. The height is reduced by about 40% relative to TADA v2, with the ankle center now at or below the height of the natural ankle.



What opportunities for training and professional development has the project provided?

If the project was not intended to provide training and professional development opportunities or there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe opportunities for training and professional development provided to anyone who worked on the project or anyone who was involved in the activities supported by the project. “Training” activities are those in which individuals with advanced professional skills and experience assist others in attaining greater proficiency. Training activities may include, for example, courses or one-on-one work with a mentor. “Professional development” activities result in increased knowledge or skill in one’s area of expertise and may include workshops, conferences, seminars, study groups, and individual study. Include participation in conferences, workshops, and seminars not listed under major activities.

Training:

Two graduate students – Rebecca Roembke and Kieran Nichols – had substantial one-on-one mentoring with Prof. Adamczyk. Mr. Nichols completed operational control of TADA v2 and executed studies of walking straight in hallways with different angles of the ankle. Ms. Roembke designed the next-generation TADA v3, built the STADA prototype, and tested it for mechanical strength on the sheep. Mr. Nichols completed his PhD.

Another graduate student, Lucas Sears, worked in the UW Department of Surgery on the surgical techniques and data processing for the sheep.

One undergraduate student, Sofya Akhetova, worked on software to coordinate sensors, control and decision making in the TADA and STADA software. She also executed a study of a stance/swing detection algorithm that is implemented to ensure the TADA moves in swing phases only.

Professional Development:

Ms. Roembke presented a poster at the American Society of Biomechanics meeting (Knoxville, TN), and another at the UW-Madison Robotics Symposium. Mr. Nichols presented a poster at the International Society of Biomechanics meeting (Fukuoka, Japan). Ms. Akhetova presented posters at the UW Undergraduate Symposium (Madison, WI) and at the Human Movement Variability and Great Plains Biomechanics Conference (Omaha, Nebraska). The conferences provided opportunities for all these students to interact extensively with other leading researchers working on wearable robots, prostheses, exoskeletons, walking robots, and more.

How were the results disseminated to communities of interest?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe how the results were disseminated to communities of interest. Include any outreach activities that were undertaken to reach members of communities who are not usually aware of these project activities, for the purpose of enhancing public understanding and increasing interest in learning and careers in science, technology, and the humanities.

Mr. Nichols presented a poster at International Society of Biomechanics 2023, and at the UW Robotics Symposium in campus.

Ms. Roembke presented a poster at American Society of Biomechanics 2023.

Ms. Akhetova presented posters at the Human Movement Variability and Great Plains Biomechanics Conference 2023 and at the UW Undergraduate Symposium on campus.

See 6. *Products* for details.

What do you plan to do during the next reporting period to accomplish the goals?

If this is the final report, state "Nothing to Report."

Describe briefly what you plan to do during the next reporting period to accomplish the goals and objectives.

In Year 4 we plan the following steps:

- Build TADA v3
- Testing TADA v3 and its controller
- Testing with persons with amputation
- Continuing refinement of the surgery to establish a functional ONI.
- Finalizing the STADA and using it in a sheep.
- Integrating the STADA with the neural interface: first via recording (to control the STADA) and then by stimulation (to feed back force or position information to the animal).
- Dissemination – manuscripts as outlined in the goals.

4. **IMPACT:** Describe distinctive contributions, major accomplishments, innovations, successes, or any change in practice or behavior that has come about as a result of the project relative to:

What was the impact on the development of the principal discipline(s) of the project?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe how findings, results, techniques that were developed or extended, or other products from the project made an impact or are likely to make an impact on the base of knowledge, theory, and research in the principal disciplinary field(s) of the project. Summarize using language that an intelligent lay audience can understand (Scientific American style).

The community associated with prosthetics development and testing continues to follow our progress on this device and its usage. Results shown in the conference posters addressed biomechanical effects of the device that will be relevant to its ultimate use. Some aspects of the design and control are relevant to other areas of biomechanics, such as the reliable real-time swing/stance detection.

What was the impact on other disciplines?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe how the findings, results, or techniques that were developed or improved, or other products from the project made an impact or are likely to make an impact on other disciplines.

Nothing to report.

What was the impact on technology transfer?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe ways in which the project made an impact, or is likely to make an impact, on commercial technology or public use, including:

- *transfer of results to entities in government or industry;*
- *instances where the research has led to the initiation of a start-up company; or*
- *adoption of new practices.*

Nothing to Report.

What was the impact on society beyond science and technology?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe how results from the project made an impact, or are likely to make an impact, beyond the bounds of science, engineering, and the academic world on areas such as:

- *improving public knowledge, attitudes, skills, and abilities;*
- *changing behavior, practices, decision making, policies (including regulatory policies), or social actions; or*
- *improving social, economic, civic, or environmental conditions.*

Nothing to report

- 5. CHANGES/PROBLEMS:** *The PD/PI is reminded that the recipient organization is required to obtain prior written approval from the awarding agency grants official whenever there are significant changes in the project or its direction. If not previously reported in writing, provide the following additional information or state, "Nothing to Report," if applicable:*

Changes in approach and reasons for change

Describe any changes in approach during the reporting period and reasons for these changes.

The TADA v2 was very fast, but also too tall, heavy and complex. TADA v3 will use a middle-ground: faster than the original, not as fast as v2, and much lighter and shorter.

Remember that significant changes in objectives and scope require prior approval of the agency.

Actual or anticipated problems or delays and actions or plans to resolve them

Describe problems or delays encountered during the reporting period and actions or plans to resolve them.

The surgical techniques for ONI implementation are improving, but have not resulted in a functional ONI yet. The prosthesis team has refocused on human testing.

Changes that had a significant impact on expenditures

Describe changes during the reporting period that may have had a significant impact on expenditures, for example, delays in hiring staff or favorable developments that enable meeting objectives at less cost than anticipated.

Nothing to Report

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Describe significant deviations, unexpected outcomes, or changes in approved protocols for the use or care of human subjects, vertebrate animals, biohazards, and/or select agents during the reporting period. If required, were these changes approved by the applicable institution committee (or equivalent) and reported to the agency? Also specify the applicable Institutional Review Board/Institutional Animal Care and Use Committee approval dates.

Significant changes in use or care of human subjects

Nothing to report

Significant changes in use or care of vertebrate animals

Nothing to report.

Significant changes in use of biohazards and/or select agents

Nothing to report

6. **PRODUCTS:** *List any products resulting from the project during the reporting period. If there is nothing to report under a particular item, state “Nothing to Report.”*

- **Publications, conference papers, and presentations**

Report only the major publication(s) resulting from the work under this award.

Journal publications. *List peer-reviewed articles or papers appearing in scientific, technical, or professional journals. Identify for each publication: Author(s); title; journal; volume; year; page numbers; status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

One publication on a prior data set, completed by the investigators during this period:

K. M. Nichols and P. G. Adamczyk, “Sensitivity of lower-limb joint mechanics to prosthetic forefoot stiffness with a variable stiffness foot in level-ground walking,” *Journal of Biomechanics*, vol. 147, p. 111436, Jan. 2023, doi: [10.1016/j.jbiomech.2023.111436](https://doi.org/10.1016/j.jbiomech.2023.111436).

Acknowledgement of federal support: yes.

Books or other non-periodical, one-time publications. *Report any book, monograph, dissertation, abstract, or the like published as or in a separate publication, rather than a periodical or series. Include any significant publication in the proceedings of a one-time conference or in the report of a one-time study, commission, or the like. Identify for each one-time publication: author(s); title; editor; title of collection, if applicable; bibliographic information; year; type of publication (e.g., book, thesis or dissertation); status of publication (published; accepted, awaiting publication; submitted, under review; other); acknowledgement of federal support (yes/no).*

Nothing to report.

Other publications, conference papers and presentations. *Identify any other publications, conference papers and/or presentations not reported above. Specify the status of the publication as noted above. List presentations made during the last year (international, national, local societies, military meetings, etc.). Use an asterisk (*) if presentation produced a manuscript.*

Roembke RA, Adamczyk PG (2023) Pylon moment of circle walking with inversion and eversion of a prosthetic ankle. American Society of Biomechanics 2023, August 8-11, 2023. Knoxville, TN, USA. Poster.

Nichols KN, Roembke RA, Akhetova S, Adamczyk PG (2023) Influence of Prosthetic ankle-angle and walking speed on Pylon moments in the Two Axis aDaptable Ankle. International Society of Biomechanics 2023, August 3-7, 2023. Fukuoka, Japan. Poster.

Akhetova S, Roembke RA, Nichols KM, Adamczyk PG (2023) Comparing Algorithms for Real-Time Toe-Off and Initial Contact Detection in Prosthetic Technology. Great Plains Biomechanics Conference & Human Movement Variability Conference 2023, June 6, 2023. Omaha, NE, USA. Poster.

Roembke RA, Akhetova S, Nichols KM, Adamczyk PG (2023) Two Axis aDaptable Ankle (TADA). UW Robotics Symposium 2023, April 28, 2023. Madison, WI, USA. Poster.

Akhetova S, Roembke RA, Nichols KM, Adamczyk PG (2023) Comparing Algorithms for Real-Time Toe-Off and Initial Contact Detection in Prosthetic Technology. UW Undergraduate Symposium 2023, April 28, 2023. Madison, WI, USA. Poster.

- **Website(s) or other Internet site(s)**

List the URL for any Internet site(s) that disseminates the results of the research activities. A short description of each site should be provided. It is not necessary to include the publications already specified above in this section.

Nothing to report.

- **Technologies or techniques**

Identify technologies or techniques that resulted from the research activities. Describe the technologies or techniques were shared.

Nothing to report.

Inventions, patent applications, and/or licenses

Identify inventions, patent applications with date, and/or licenses that have resulted from the research. Submission of this information as part of an interim research performance progress report is not a substitute for any other invention reporting required under the terms and conditions of an award.

Nothing to report

- **Other Products**

Identify any other reportable outcomes that were developed under this project. Reportable outcomes are defined as a research result that is or relates to a product, scientific advance, or research tool that makes a meaningful contribution toward the understanding, prevention, diagnosis, prognosis, treatment and /or rehabilitation of a disease, injury or condition, or to improve the quality of life. Examples include:

- *data or databases;*

- *physical collections;*
- *audio or video products;*
- *software;*
- *models;*
- *educational aids or curricula;*
- *instruments or equipment;*
- *research material (e.g., Germplasm; cell lines, DNA probes, animal models);*
- *clinical interventions;*
- *new business creation; and*
- *other.*

Nothing to report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Provide the following information for: (1) PDs/PIs; and (2) each person who has worked at least one person month per year on the project during the reporting period, regardless of the source of compensation (a person month equals approximately 160 hours of effort). If information is unchanged from a previous submission, provide the name only and indicate “no change”.

Name: Peter Adamczyk
Project Role: PI
Researcher Identifier (ORCID): 0000-0001-5374-7691
Nearest person month worked: 1
Contribution to Project: Dr. Adamczyk worked to direct the training of both graduate students and their development of the Two-Axis ‘Daptable Ankle (TADA).

Name: Kieran Nichols
Project Role: Graduate Student
Researcher Identifier (ORCID): none
Nearest person month worked: 6
Contribution to Project: Mr. Nichols finalized the controller and used it to complete the hallway testing with the TADA v2. He prepared his dissertation and drafted two manuscripts. He also brought to publication a paper on a prior data set.

Name: Rebecca Roembke
Project Role: Graduate Student
Researcher Identifier (ORCID): none
Nearest person month worked: 6
Contribution to Project: Ms. Roembke maintained and tuned the TADA v2 and and near-finalized STADA v1.

Name: Sofya Akhetova
Project Role: Undergraduate Student
Researcher Identifier (ORCID): none
Nearest person month worked: 2
Contribution to Project: Ms. Akhetova worked on control for TADA v2 and STADA. She also developed a swing vs. stance phase detection algorithm and tested it, and is preparing a manuscript on it.

Name: Lucas Sears
Project Role: Graduate Student
Researcher Identifier (ORCID): unknown
Nearest person month worked: 2
Contribution to Project: Mr. Sears worked on electrophysiology and surgical techniques for the osseointegrated implant.

Name: Samuel Poore
Project Role: Senior Personnel
Researcher Identifier (ORCID): unknown
Nearest person month worked: 1
Contribution to Project: Dr. Poore worked to develop and practice the implantation procedure for the ovine model.

Name: Aaron Dingle
Project Role: Co-Investigator
Researcher Identifier (ORCID): unknown
Nearest person month worked: 1
Contribution to Project: Dr. Dingle worked to develop and practice the implantation procedure for the ovine model, and coordinated efforts across the surgical, implant, and neural interface teams.

Name: Aaron Suminski
Project Role: Senior Personnel
Researcher Identifier (ORCID): unknown
Nearest person month worked: 1
Contribution to Project: Dr. Suminski advised on neural interface development and implementation.

Name: Weifeng Zeng
Project Role: Senior Personnel
Researcher Identifier (ORCID): unknown
Nearest person month worked: 1
Contribution to Project: Dr. Zeng is part of the surgical team working on implantation techniques.

Name: Yan Lu
Project Role: Senior Personnel
Researcher Identifier (ORCID): unknown
Nearest person month worked: 1
Contribution to Project: Dr. Lu is part of the surgical team working on implantation techniques.

Name: Brett Nemke
Project Role: Research Manager
Researcher Identifier (ORCID): unknown
Nearest person month worked: 2
Contribution to Project: Mr. Nemke helped organize the many moving parts of the surgery side of the project.

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

If the active support has changed for the PD/PI(s) or senior/key personnel, then describe what the change has been. Changes may occur, for example, if a previously active grant has closed and/or if a previously pending grant is now active. Annotate this information so it is clear what has changed from the previous submission. Submission of other support information is not necessary for pending changes or for changes in the level of effort for active support reported previously. The awarding agency may require prior written approval if a change in active other support significantly impacts the effort on the project that is the subject of the project report.

Nothing to Report.

What other organizations were involved as partners?

If there is nothing significant to report during this reporting period, state “Nothing to Report.”

Describe partner organizations – academic institutions, other nonprofits, industrial or commercial firms, state or local governments, schools or school systems, or other organizations (foreign or domestic) – that were involved with the project. Partner organizations may have provided financial or in-kind support, supplied facilities or equipment, collaborated in the research, exchanged personnel, or otherwise contributed.

Provide the following information for each partnership:

Organization Name:

Location of Organization: (if foreign location list country)

Partner’s contribution to the project (identify one or more)

- *Financial support;*
- *In-kind support (e.g., partner makes software, computers, equipment, etc.,*

- *available to project staff);*
- *Facilities (e.g., project staff use the partner's facilities for project activities);*
- *Collaboration (e.g., partner's staff work with project staff on the project);*
- *Personnel exchanges (e.g., project staff and/or partner's staff use each other's facilities, work at each other's site); and*
- *Other.*

Organization: Duke University

Location: Durham, NC, USA

Contribution: Work on neural interface system for the Sheep portion of the project.

Organization: University of Utah

Location: Salt Lake City, UT, USA

Contribution: Work on osseointegration implants for the Sheep portion of the project.

8. SPECIAL REPORTING REQUIREMENTS

COLLABORATIVE AWARDS: *For collaborative awards, independent reports are required from BOTH the Initiating Principal Investigator (PI) and the Collaborating/Partnering PI. A duplicative report is acceptable; however, tasks shall be clearly marked with the responsible PI and research site. A report shall be submitted to <https://ers.amedd.army.mil> for each unique award.*

QUAD CHARTS: *If applicable, the Quad Chart (available on <https://www.usamraa.army.mil>) should be updated and submitted with attachments.*

9. **APPENDICES:** *Attach all appendices that contain information that supplements, clarifies or supports the text. Examples include original copies of journal articles, reprints of manuscripts and abstracts, a curriculum vitae, patent applications, study questionnaires, and surveys, etc.*