



Steven Hartley Collins

Associate Professor of Mechanical Engineering

Bio

BIO

Steve Collins is an Associate Professor of Mechanical Engineering at Stanford University, where he teaches courses on design and robotics and directs the Stanford Biomechatronics Laboratory. His primary focus is to speed and systematize the design and prescription of prostheses and exoskeletons using versatile device emulator hardware and human-in-the-loop optimization algorithms (Zhang et al. 2017, Science). Another interest is efficient autonomous devices, such as highly energy-efficient walking robots (Collins et al. 2005, Science) and exoskeletons that use no energy yet reduce the metabolic energy cost of human walking (Collins et al. 2015, Nature).

Prof. Collins received his B.S. in Mechanical Engineering in 2002 from Cornell University, where he performed undergraduate research on passive dynamic walking robots. He received his Ph.D. in Mechanical Engineering in 2008 from the University of Michigan, where he performed research on the dynamics and control of human walking. He performed postdoctoral research on humanoid robots at T. U. Delft in the Netherlands. He was a professor of Mechanical Engineering and Robotics at Carnegie Mellon University for seven years. In 2017, he joined the faculty of Mechanical Engineering at Stanford University.

Prof. Collins is a member of the Scientific Board of Dynamic Walking and the Editorial Board of Science Robotics. He has received the Young Scientist Award from the American Society of Biomechanics, the Best Medical Devices Paper from the International Conference on Robotics and Automation, and the student-voted Professor of the Year in his department.

ACADEMIC APPOINTMENTS

- Associate Professor, Mechanical Engineering
- Member, Bio-X
- Faculty Affiliate, Institute for Human-Centered Artificial Intelligence (HAI)
- Member, Wu Tsai Human Performance Alliance
- Member, Wu Tsai Neurosciences Institute

HONORS AND AWARDS

- Chambers Faculty Scholar, Stanford School of Engineering (2020-2024)
- Teaching Honor Roll, Tau Beta Pi of Stanford University (2020)
- Best Medical Robotics Paper Award, International Conference on Robotics and Automation (ICRA) (2015)
- Professor of the Year (student-voted), Department of Mechanical Engineering, Carnegie Mellon University (2014)
- Young Scientist Award, Post-Doctoral, American Society for Biomechanics (2013)
- Struminger Faculty Teaching Fellow, Department of Mechanical Engineering, Carnegie Mellon University (2012)

- McManus Design Award, Department of Mechanical Engineering, Cornell University (2002)

BOARDS, ADVISORY COMMITTEES, PROFESSIONAL ORGANIZATIONS

- Editorial Board, Science Robotics (2019 - present)
- Associate Editor, International Journal of Robotics Research (2017 - 2019)
- Scientific Board, Dynamic Walking (2008 - present)

PROFESSIONAL EDUCATION

- Ph.D., University of Michigan , Mechanical Engineering (2008)
- B.S., Cornell University , Mechanical Engineering (2002)

LINKS

- Stanford Biomechanics Laboratory: <http://biomechanics.stanford.edu>
- Personal Website: <http://web.stanford.edu/people/stevecollins>
- Publications on Google Scholar: <http://scholar.google.com/citations?user=eF5vfBAAAAAJ>

Teaching

COURSES

2022-23

- Mechanical Systems Design: ME 104 (Win, Spr)
- The Future of Mechanical Engineering Education: ME 228T (Win)

2021-22

- Mechanical Systems Design: ME 104 (Win, Spr)

2020-21

- Mechanical Systems Design: ME 104 (Win, Spr)

2019-20

- Mechanical Systems Design: ME 104 (Win, Spr)

STANFORD ADVISEES

Postdoctoral Faculty Sponsor

Jinsoo Kim, Jiaen Wu

Doctoral Dissertation Advisor (AC)

Erez Krimsky, Ava Lakmazaheri, Russell Martin, Delaney Miller, Michael Raitor, Andrew Zerbe

Master's Program Advisor

Blake Biskner, Jonathan Sosa

Publications

PUBLICATIONS

- **Human-in-the-loop optimization of exoskeleton assistance during walking** *SCIENCE*
Zhang, J., Fiers, P., Witte, K. A., Jackson, R. W., Poggensee, K. L., Atkeson, C. G., Collins, S. H.
2017; 356: 1280-1284

- **Reducing the energy cost of human walking using an unpowered exoskeleton** *NATURE*
Collins, S. H., Wiggin, M. B., Sawicki, G. S.
2015; 522 (7555): 212-?
- **Efficient bipedal robots based on passive-dynamic walkers** *SCIENCE*
Collins, S., Ruina, A., Tedrake, R., Wisse, M.
2005; 307 (5712): 1082-1085
- **Robotic Emulation of Candidate Prosthetic Foot Designs May Enable Efficient, Evidence-Based, and Individualized Prescriptions.** *Journal of prosthetics and orthotics : JPO*
Caputo, J. M., Dvorak, E., Shipley, K., Miknevich, M. A., Adamczyk, P. G., Collins, S. H.
2022; 34 (4): 202-212
- **The Effects of Incline Level on Optimized Lower-Limb Exoskeleton Assistance: a Case Series.** *IEEE transactions on neural systems and rehabilitation engineering : a publication of the IEEE Engineering in Medicine and Biology Society*
Franks, P. W., Bryan, G. M., Reyes, R., O'Donovan, M. P., Gregorczyk, K. N., Collins, S. H.
2022; PP
- **The split-belt rimless wheel** *INTERNATIONAL JOURNAL OF ROBOTICS RESEARCH*
Butterfield, J. K., Simha, S. N., Donelan, J., Collins, S. H.
2022
- **Characterizing the relationship between peak assistance torque and metabolic cost reduction during running with ankle exoskeletons.** *Journal of neuroengineering and rehabilitation*
Miller, D. E., Tan, G. R., Farina, E. M., Sheets-Singer, A. L., Collins, S. H.
2022; 19 (1): 46
- **General variability leads to specific adaptation toward optimal movement policies.** *Current biology : CB*
Abram, S. J., Poggensee, K. L., Sanchez, N., Simha, S. N., Finley, J. M., Collins, S. H., Donelan, J. M.
2022
- **The energy cost of split-belt walking for a variety of belt speed combinations.** *Journal of biomechanics*
Butterfield, J. K., Collins, S. H.
2022; 132: 110905
- **Five years of Science Robotics.** *Science robotics*
Yang, G., Collins, S. H., Dario, P., Fischer, P., Goldberg, K., Laschi, C., McNutt, M. K.
1800; 6 (61): eabn2720
- **Optimized hip-knee-ankle exoskeleton assistance reduces the metabolic cost of walking with worn loads.** *Journal of neuroengineering and rehabilitation*
Bryan, G. M., Franks, P. W., Song, S., Reyes, R., O'Donovan, M. P., Gregorczyk, K. N., Collins, S. H.
2021; 18 (1): 161
- **Optimized hip-knee-ankle exoskeleton assistance at a range of walking speeds.** *Journal of neuroengineering and rehabilitation*
Bryan, G. M., Franks, P. W., Song, S., Voloshina, A. S., Reyes, R., O'Donovan, M. P., Gregorczyk, K. N., Collins, S. H.
2021; 18 (1): 152
- **How adaptation, training, and customization contribute to benefits from exoskeleton assistance.** *Science robotics*
Poggensee, K. L., Collins, S. H.
2021; 6 (58): eabf1078
- **Shortcomings of human-in-the-loop optimization of an ankle-foot prosthesis emulator: a case series.** *Royal Society open science*
Welker, C. G., Voloshina, A. S., Chiu, V. L., Collins, S. H.
2021; 8 (5): 202020
- **The effects of ground-irregularity-cancelling prosthesis control on balance over uneven surfaces.** *Royal Society open science*
Chiu, V. L., Voloshina, A. S., Collins, S. H.
2021; 8 (1): 201235
- **Optimizing Exoskeleton Assistance for Faster Self-Selected Walking** *IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING*

- Song, S., Collins, S. H.
2021; 29: 786-795
- **Comparing optimized exoskeleton assistance of the hip, knee, and ankle in single and multi-joint configurations** *Wearable Technologies*
Franks, P. W., Bryan, G. M., Martin, R. M., Reyes, R., Lakmazaheri, A. C., Collins, S. H.
2021; 2
 - **The Iterative Learning Gain That Optimizes Real-Time Torque Tracking for Ankle Exoskeletons in Human Walking Under Gait Variations.** *Frontiers in neurorobotics*
Zhang, J., Collins, S. H.
2021; 15: 653409
 - **Human Perception of Wrist Torque Magnitude During Upper and Lower Extremity Movement**
Welker, C., Collins, S. H., Okamura, A. M., IEEE
IEEE.2021: 870
 - **Weighted Shoes in the Wild: Initial Insights into the Relationship Between the Effort of Walking and the Amount of Walking Performed**
Wu, M. R., Adamczyk, P. G., Collins, S. H.
bioRxiv.
2021
 - **Design of a hip exoskeleton with actuation in frontal and sagittal planes** *Transactions on Medical Robotics and Bionics*
Chiu, V., Raitor, M., Collins, S. H.
2021; 3: 773-782
 - **Robotic emulation of candidate prosthetic foot designs may enable efficient, evidence-based, and individualized prescriptions** *Journal of Prosthetics and Orthotics*
Caputo, J. M., Dvorak, E., Shipley, K., Miknevich, M., Adamczyk, P. G., Collins, S. H.
2021: 11 pages
 - **Sensing leg movement enhances wearable monitoring of energy expenditure.** *Nature communications*
Slade, P., Kochenderfer, M. J., Delp, S. L., Collins, S. H.
2021; 12 (1): 4312
 - **A hip-knee-ankle exoskeleton emulator for studying gait assistance** *The International Journal of Robotics Research*
Bryan, G. M., Franks, P. W., Klein, S. C., Peuchen, R. J., Collins, S. H.
2021
 - **Self-selected step length asymmetry is not explained by energy cost minimization in individuals with chronic stroke.** *Journal of neuroengineering and rehabilitation*
Nguyen, T. M., Jackson, R. W., Aucie, Y., de Kam, D., Collins, S. H., Torres-Oviedo, G.
2020; 17 (1): 119
 - **Prosthesis Inversion/Eversion Stiffness Reduces Balance-Related Variability During Level Walking.** *Journal of biomechanical engineering*
Kim, M., Lyness, H., Chen, T., Collins, S.
2020
 - **Combating COVID-19-The role of robotics in managing public health and infectious diseases** *SCIENCE ROBOTICS*
Yang, G., Nelson, B. J., Murphy, R. R., Choset, H., Christensen, H., Collins, S. H., Dario, P., Goldberg, K., Ikuta, K., Jacobstein, N., Kragic, D., Taylor, R. H., McNutt, et al
2020; 5 (40)
 - **Improving the energy economy of human running with powered and unpowered ankle exoskeleton assistance.** *Science robotics*
Witte, K. A., Fiers, P., Sheets-Singer, A. L., Collins, S. H.
2020; 5 (40)
 - **Using force data to self-pace an instrumented treadmill and measure self-selected walking speed.** *Journal of neuroengineering and rehabilitation*
Song, S. n., Choi, H. n., Collins, S. H.
2020; 17 (1): 68
 - **Bump'em: an Open-Source, Bump-Emulation System for Studying Human Balance and Gait**

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- Tan, G., Raitor, M., Collins, S. H., IEEE
IEEE.2020: 9093-9099
- **DESIGN OF LOWER-LIMB EXOSKELETONS AND EMULATOR SYSTEMS** *WEARABLE ROBOTICS: SYSTEMS AND APPLICATIONS*
Witte, K., Collins, S. H., Rosen, J., Ferguson, P. W.
2020: 251-274
 - **LOWER LIMB ACTIVE PROSTHETIC SYSTEMS-OVERVIEW** *WEARABLE ROBOTICS: SYSTEMS AND APPLICATIONS*
Voloshina, A. S., Collins, S. H., Rosen, J., Ferguson, P. W.
2020: 469-486
 - **Testing Simulated Assistance Strategies on a Hip-Knee-Ankle Exoskeleton: a Case Study** *International Conference on Biomedical Robotics and Biomechanics*
Franks, P. W., Bianco, N. A., Bryan, G. M., Hicks, J. L., Delp, S. L., Collins, S. H.
2020: 700–707
 - **Optimal Control of an Energy-Recycling Actuator for Mobile Robotics Applications** *International Conference on Robotics and Automation*
Krimsky, E., Collins, S. H.
2020: 3559–3565
 - **Teleoperation of an ankle-foot prosthesis with a wrist exoskeleton.** *IEEE transactions on bio-medical engineering*
Welker, C. G., Chiu, V. L., Voloshina, A. n., Collins, S. n., Okamura, A. M.
2020; PP
 - **Bump'em: an Open-Source, Bump-Emulation System for Studying Human Balance and Gait** *International Conference on Robotics and Automation*
Tan, G. R., Raitor, M., Collins, S. H.
2020: 9093–9099
 - **An Ankle-Foot Prosthesis Emulator Capable of Modulating Center of Pressure** *IEEE TRANSACTIONS ON BIOMEDICAL ENGINEERING*
Chiu, V. L., Voloshina, A. S., Collins, S. H.
2020; 67 (1): 166–76
 - **Heuristic-Based Ankle Exoskeleton Control for Co-Adaptive Assistance of Human Locomotion** *IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING*
Jackson, R. W., Collins, S. H.
2019; 27 (10): 2059–69
 - **Connecting the legs with a spring improves human running economy.** *The Journal of experimental biology*
Simpson, C. S., Welker, C. G., Uhlrich, S. D., Sketch, S. M., Jackson, R. W., Delp, S. L., Collins, S. H., Selinger, J. C., Hawkes, E. W.
2019
 - **Design of lower-limb exoskeletons and emulator systems** *Wearable Robotics: Systems and Applications*
Witte, K. A., Collins, S. H.
2019: 251–274
 - **Rapid energy expenditure estimation for ankle assisted and inclined loaded walking.** *Journal of neuroengineering and rehabilitation*
Slade, P. n., Troutman, R. n., Kochenderfer, M. J., Collins, S. H., Delp, S. L.
2019; 16 (1): 67
 - **A review of design and control approaches in lower-limb prosthetic devices** *Wearable Robotics: Systems and Applications*
Voloshina, A. S., Collins, S. H.
2019: 469–486
 - **The effects of electroadhesive clutch design parameters on performance characteristics** *JOURNAL OF INTELLIGENT MATERIAL SYSTEMS AND STRUCTURES*
Diller, S. B., Collins, S. H., Majidi, C.
2018; 29 (19): 3804–28
 - **An Ankle-Foot Prosthesis Emulator With Control of Plantarflexion and Inversion-Eversion Torque** *IEEE TRANSACTIONS ON ROBOTICS*
Kim, M., Chen, T., Chen, T., Collins, S. H.
2018; 34 (5): 1183–94

- **The Passive Series Stiffness That Optimizes Torque Tracking for a Lower-Limb Exoskeleton in Human Walking** *FRONTIERS IN NEUROBOTICS*
Zhang, J., Collins, S. H.
2017; 11: 68
- **Step-to-Step Ankle Inversion/Eversion Torque Modulation Can Reduce Effort Associated with Balance.** *Frontiers in neurobotics*
Kim, M., Collins, S. H.
2017; 11: 62
- **Muscle recruitment and coordination with an ankle exoskeleton** *JOURNAL OF BIOMECHANICS*
Steele, K. M., Jackson, R. W., Shuman, B. R., Collins, S. H.
2017; 59: 50–58
- **Muscle-tendon mechanics explain unexpected effects of exoskeleton assistance on metabolic rate during walking.** *journal of experimental biology*
Jackson, R. W., Dembia, C. L., Delp, S. L., Collins, S. H.
2017; 220: 2082-2095
- **Reducing the metabolic cost of walking with an ankle exoskeleton: interaction between actuation timing and power.** *Journal of neuroengineering and rehabilitation*
Galle, S., Malcolm, P., Collins, S. H., De Clercq, D.
2017; 14 (1): 35-?
- **Once-Per-Step Control of Ankle Push-Off Work Improves Balance in a Three-Dimensional Simulation of Bipedal Walking** *IEEE TRANSACTIONS ON ROBOTICS*
Kim, M., Collins, S. H.
2017; 33 (2): 406-418
- **Design of a lightweight, tethered, torque-controlled knee exoskeleton** *International Conference on Rehabilitation Robotics (ICORR)*
Witte, K. A., Fatschel, A. M., Collins, S. H.
2017: 1646–53
- **Torque control in legged locomotion** *Bio-Inspired Legged Locomotion: Models, Concepts, Control and Applications*
Zhang, J., Collins, S. H.
2017: 347–395
- **Increasing ankle push-off work with a powered prosthesis does not necessarily reduce metabolic rate for transtibial amputees** *JOURNAL OF BIOMECHANICS*
Quesada, R. E., Caputo, J. M., Collins, S. H.
2016; 49 (14): 3452-3459
- **A lightweight, low-power electroadhesive clutch and spring for exoskeleton actuation** *International Conference on Robotics and Automation*
Diller, S., Majidi, C., Collins, S. H.
2016: 682–689
- **An experimental comparison of the relative benefits of work and torque assistance in ankle exoskeletons** *JOURNAL OF APPLIED PHYSIOLOGY*
Jackson, R. W., Collins, S. H.
2015; 119 (5): 541-557
- **Once-per-step control of ankle-foot prosthesis push-off work reduces effort associated with balance during walking** *JOURNAL OF NEUROENGINEERING AND REHABILITATION*
Kim, M., Collins, S. H.
2015; 12
- **The influence of push-off timing in a robotic ankle-foot prosthesis on the energetics and mechanics of walking** *JOURNAL OF NEUROENGINEERING AND REHABILITATION*
Malcolm, P., Quesada, R. E., Caputo, J. M., Collins, S. H.
2015; 12
- **Experimental comparison of torque control methods on an ankle exoskeleton during human walking**
Zhang, J., Cheah, C., Collins, S. H., IEEE
IEEE COMPUTER SOC.2015: 5584–89

- **Informing Ankle-Foot Prosthesis Prescription through Haptic Emulation of Candidate Devices**
Caputo, J. M., Adamczyk, P. G., Collins, S. H., IEEE
IEEE COMPUTER SOC.2015: 6445–50
- **An Ankle-Foot Prosthesis Emulator with Control of Plantarflexion and Inversion-Eversion Torque**
Collins, S. H., Kim, M., Chen, T., Chen, T., IEEE
IEEE COMPUTER SOC.2015: 1210–16
- **Design of Two Lightweight, High-Bandwidth Torque-Controlled Ankle Exoskeletons**
Witte, K., Zhang, J., Jackson, R. W., Collins, S. H., IEEE
IEEE COMPUTER SOC.2015: 1223–28
- **Prosthetic ankle push-off work reduces metabolic rate but not collision work in non-amputee walking** *SCIENTIFIC REPORTS*
Caputo, J. M., Collins, S. H.
2014; 4
- **A Universal Ankle-Foot Prosthesis Emulator for Human Locomotion Experiments** *JOURNAL OF BIOMECHANICAL ENGINEERING-TRANSACTIONS OF THE ASME*
Caputo, J. M., Collins, S. H.
2014; 136 (3)
- **Emulating prosthetic feet during the prescription process to improve outcomes and justifications**
Caputo, J. M., Collins, S. H., Adamczyk, P. G., IEEE
IEEE.2014: 127–28
- **Two Independent Contributions to Step Variability during Over-Ground Human Walking** *PLOS ONE*
Collins, S. H., Kuo, A. D.
2013; 8 (8)
- **Inducing Self-Selected Human Engagement in Robotic Locomotion Training**
Collins, S. H., Jackson, R. W., IEEE
IEEE.2013
- **What Do Walking Humans Want From Mechatronics?**
Collins, S. H., IEEE
IEEE.2013
- **An Experimental Robotic Testbed for Accelerated Development of Ankle Prostheses**
Caputo, J. M., Collins, S. H., IEEE
IEEE.2013: 2645–50
- **Stable Human-Robot Interaction Control for Upper-limb Rehabilitation Robotics**
Zhang, J., Cheah, C., Collins, S. H., IEEE
IEEE.2013: 2201–6
- **The Effect of Foot Compliance Encoded in the Windlass Mechanism on the Energetics of Human Walking**
Song, S., LaMontagna, C., Collins, S. H., Geyer, H., IEEE
IEEE.2013: 3179–82
- **Stabilization of a Three-Dimensional Limit Cycle Walking Model through Step-to-Step Ankle Control**
Kim, M., Collins, S. H., IEEE
IEEE.2013
- **The effects of a controlled energy storage and return prototype prosthetic foot on transtibial amputee ambulation** *HUMAN MOVEMENT SCIENCE*
Segal, A. D., Zelik, K. E., Klute, G. K., Morgenroth, D. C., Hahn, M. E., Orendurff, M. S., Adamczyk, P. G., Collins, S. H., Kuo, A. D., Czerniecki, J. M.
2012; 31 (4): 918–31
- **The effect of ankle foot orthosis stiffness on the energy cost of walking: A simulation study** *CLINICAL BIOMECHANICS*
Bregman, D. J., van der Krogt, M. M., de Groot, V., Harlaar, J., Wisse, M., Collins, S. H.
2011; 26 (9): 955–61

- **The effect of prosthetic foot push-off on mechanical loading associated with knee osteoarthritis in lower extremity amputees** *GAIT & POSTURE*
Morgenroth, D. C., Segal, A. D., Zelik, K. E., Czerniecki, J. M., Klute, G. K., Adamczyk, P. G., Orendurff, M. S., Hahn, M. E., Collins, S. H., Kuo, A. D.
2011; 34 (4): 502-507
- **Systematic Variation of Prosthetic Foot Spring Affects Center-of-Mass Mechanics and Metabolic Cost During Walking** *IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING*
Zelik, K. E., Collins, S. H., Adamczyk, P. G., Segal, A. D., Klute, G. K., Morgenroth, D. C., Hahn, M. E., Orendurff, M. S., Czerniecki, J. M., Kuo, A. D.
2011; 19 (4): 411-419
- **An Exoskeleton Using Controlled Energy Storage and Release to Aid Ankle Propulsion**
Wiggin, M., Sawicki, G. S., Collins, S. H., IEEE
IEEE.2011
- **How Crouch Gait Can Dynamically Induce Stiff-Knee Gait** *ANNALS OF BIOMEDICAL ENGINEERING*
van der Krogt, M. M., Bregman, D. J., Wisse, M., Doorenbosch, C. M., Harlaar, J., Collins, S. H.
2010; 38 (4): 1593-1606
- **Recycling Energy to Restore Impaired Ankle Function during Human Walking** *PLOS ONE*
Collins, S. H., Kuo, A. D.
2010; 5 (2): e9307
- **Dynamic arm swinging in human walking** *PROCEEDINGS OF THE ROYAL SOCIETY B-BIOLOGICAL SCIENCES*
Collins, S. H., Adamczyk, P. G., Kuo, A. D.
2009; 276 (1673): 3679-88
- **A simple method for calibrating force plates and force treadmills using an instrumented pole** *GAIT & POSTURE*
Collins, S. H., Adamczyk, P. G., Ferris, D. P., Kuo, A. D.
2009; 29 (1): 59-64
- **Ankle fixation need not increase the energetic cost of human walking** *GAIT & POSTURE*
Vanderpool, M. T., Collins, S. H., Kuo, A. D.
2008; 28 (3): 427-33
- **The advantages of a rolling foot in human walking** *JOURNAL OF EXPERIMENTAL BIOLOGY*
Adamczyk, P. G., Collins, S. H., Kuo, A. D.
2006; 209 (20): 3953-63
- **A bipedal walking robot with efficient and human-like gait**
Collins, S. H., Ruina, A., IEEE
IEEE.2005: 1983-88
- **The RoboKnee: An exoskeleton for enhancing strength and endurance during walking**
Pratt, J. E., Krupp, B. T., Morse, C. J., Collins, S. H., IEEE
IEEE.2004: 2430-35
- **A three-dimensional passive-dynamic walking robot with two legs and knees** *INTERNATIONAL JOURNAL OF ROBOTICS RESEARCH*
Collins, S. H., Wisse, M., Ruina, A.
2001; 20 (7): 607-15