

Evaluating Learning on a Limb: A high school orthopaedic research outreach workshop

Christopher J. Panebianco¹, Tala F. Azar¹, Michael P. Duffy¹, Talayah Johnson¹, Annemarie Lang¹, Madhura P. Nijssure¹, Karthik Rajagopal¹, Jamie Santillan¹, Margaret Tamburro¹, Robert L. Mauck^{1,2}, Louis J. Soslowsky^{1,2}, Eileen M. Shore¹, Jamie Shuda³, Sarah E. Gullbrand^{1,2}

¹Department of Orthopaedic Surgery, University of Pennsylvania, Philadelphia, PA, ²Translational Musculoskeletal Research Center, Crescenz VA Medical Center, Philadelphia, PA, ³Institute for Regenerative Medicine, University of Pennsylvania, Philadelphia, PA

INTRODUCTION: Musculoskeletal disorders cost approximately \$380.9 billion annually, making them the aggregated health category with the greatest spending in the United States.¹ Combating these high economic costs and the burden that musculoskeletal disorders have on the global population will require diverse research teams, which produce higher impact work.² To establish diverse research teams in orthopaedics, targeted efforts to recruit young, diverse students to the field are needed. One effective way of engaging K-12 students to study science, technology, engineering, and mathematics (STEM) is outreach activities.³ Last year, our group designed and implemented Learning on a Limb, a half-day workshop to teach high school students about orthopaedic research.⁴ We have now incorporated expanded rigorous evaluation metrics to determine how effectively this workshop taught principles of orthopaedic research and inspired high school students to consider careers in orthopaedics.

METHODS: The workshop, called Learning on a Limb, was planned and executed by the McKay Orthopaedic Research Laboratory's Diversity, Equity, and Inclusion (DEI) Committee and the Perelman School of Medicine (PSOM) Office of Outreach, Education, and Research. The Learning on a Limb Team was a diverse group of principal investigators, postdoctoral research fellows, and graduate students who all conduct orthopaedic research. High school students were recruited to participate in Learning on a Limb by the PSOM Office of Outreach, Education, and Research through flyers sent to high schools in the Greater Philadelphia area. The workshop can be divided into 3 stages: (1) Pre-activity exercises, (2) hands-on activities, and (3) post-activity exercises. During the pre-activity exercise, instructors provided students with a brief background on orthopaedic tissues and the techniques they would learn during the hands-on activities. For the hands-on activities, students were divided into four groups for circuit-style, hands-on breakout sessions. Each group consisted of 3-4 students that completed each of the following activities: (1) biomechanical testing of healthy and diseased rat tendons, (2) microcomputed tomography analysis of healthy and diseased rat bones, (3) culture of mouse bone marrow mesenchymal stem cells, and (4) histological assessment of intervertebral discs and tendons from humans, rabbits, and rats. Groups worked with Learning on a Limb instructors to complete each activity, spending approximately 25 min per activity. After completing the hands-on activities, students participated in a post-activity discussion about what they learned and a speed-networking discussion with diverse members of the Learning on a Limb Team. The workshop was evaluated using pre/post-tests to assess learning gains and a post-survey to assess interest in orthopaedic and biomedical engineering research. The pre/post-test consisted of 8 multiple-choice questions (2 per activity). Average pre/post-test results were compared using paired Student's t-tests ($\alpha = 0.05$). This study was approved by the University of Pennsylvania Institutional Review Board.

RESULTS: 12 high school students participated in our Learning on a Limb workshop. Most students identified as female (N=7, 58.33%). Additionally, students in our cohort identified as black (N=4, 33.33%), Latinx (N=1, 8.33%), Asian (N=6, 50%) and other (N=1, 8.33%). Thus, a large portion of the students in our cohort were considered gender and racial minorities in STEM. Results from our pre/post-test showed that students experienced significant learning gains from participating in Learning on a Limb. Specifically, the average score increased from 24.0% on the pre-test to 82.3% on the post-test (Fig 1A). In addition to increases in overall score, we found that the percentage of students who answered each test question (TQ) correct was greater in the post-test than the pre-test (Fig 1B). Our post-survey assessment demonstrated that Learning on a Limb also had a positive influence on students' interest in orthopaedic and biomedical engineering research (Fig 2). After completing the workshop, at least half of the students indicated that Learning on a Limb influenced their interest in learning about orthopaedics research (SQ1 & SQ2), pursuing careers in orthopaedics (SQ3), and learning about biomedical engineering (SQ4 and SQ5). Less than half of the students' felt that Learning on a Limb influenced their interest in pursuing a career in biomedical engineering (SQ6), which was plausible since the goal of the workshop was orthopaedics and not necessarily biomedical engineering. Additional comments on the post-survey indicated that students had fun participating in all aspects of Learning on a Limb (*i.e.*, hands-on activities and conversations with the Learning on a Limb Team). Overall, our results demonstrate that completing this workshop was a fun and effective way to teach students about orthopaedics and spark their interest in orthopaedic research.

DISCUSSION: Orthopaedic research is necessary to combat the high economic and societal burden that musculoskeletal diseases place on the world. To continue advancing orthopaedic research, there is a need to teach diverse students about orthopedic research at a young age. Towards this goal, we designed, implemented, and evaluated Learning on a Limb, a half-day workshop to introduce high school students to the field of orthopaedics. We found that our workshop effectively taught principles of orthopaedics and sparked student interest in orthopaedics. Given the success of this workshop, we plan to conduct Learning on a Limb annually as a means of promoting diverse participation in orthopaedic research. We will also leverage our partnership with the PSOM Office of Outreach, Education, and Research to longitudinally track the students who participated in Learning on a Limb, as has been done in the field of reproductive health⁵ and for women in orthopaedics through the Perry Initiative.⁶ This long-term longitudinal tracking of students' college and career choices will allow us to more rigorously evaluate the long-term benefits students received from participating in Learning on a Limb.

SIGNIFICANCE: Developing engaging workshops for high school students is important for increasing diverse participation in orthopaedics. Learning on a Limb is an effective workshop, which orthopaedics department can use as a model to inspire the next generation of orthopaedic researchers.

REFERENCES: [1] Dieleman+ *JAMA* 2020, [2] Valantine+ *CBE Life Sci Edu* 2016, [3] Spencer+ *BMJ* 1999, [4] Assi+ *Trans ORS* 2023, [5] Castle+ *Biol Reprod* 2016, [6] Buckley+ *J Am Acad Orthop Surg* 2022

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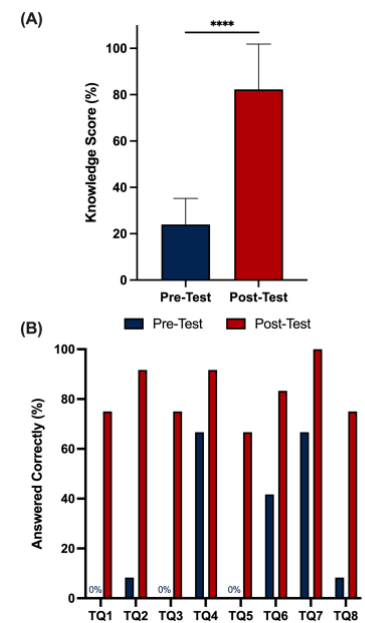


Figure 1. Students showed significant learning gains by pre/post-test. (A) Average pre/post-test scores. (B) Percentage of students who answered individual test questions (TQs) correctly. **** = $p < 0.0001$.

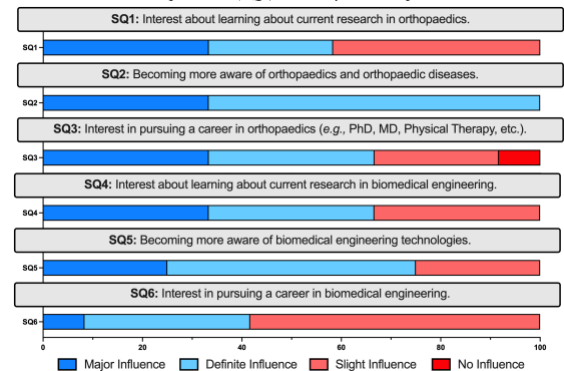


Figure 2. Post-survey data showing future interest in orthopaedics.