A. COVER PAGE

Project Title: Using computer vision and deep learning to measure worker kinematics	
Grant Number: 5R21OH011911-02	**Project/Grant Period:** 09/30/2021 - 09/29/2023
Reporting Period: 09/30/2022 - 09/29/2023	**Requested Budget Period:** 09/30/2022 - 09/29/2023
Report Term Frequency: Final	**Date Submitted:** 01/02/2024
Program Director/Principal Investigator Information: NATHAN B FETHKE , BS MS PHD **Phone Number:** 3194674563 **Email:** nathan-fethke@uiowa.edu	**Recipient Organization:** UNIVERSITY OF IOWA UNIVERSITY OF IOWA 2 Gilmore Hall, 112 N Capitol Street IOWA CITY, IA 522421320 **DUNS:** 062761671 **UEI:** Z1H9VJS8NG16 **EIN:** 1426004813A1 **RECIPIENT ID:**
Change of Contact PD/PI: NA	
Administrative Official: WENDY BEAVER 2 Gilmore Hall Iowa City, IA 52242 **Phone number:** 319-335-2123 **Email:** nih@uiowa.edu	**Signing Official:** MARTIN SCHOLTZ 3-770 BSB Iowa City, IA 522421320 **Phone number:** 3193352123 **Email:** nih@uiowa.edu
Human Subjects: NA	**Vertebrate Animals:** NA
hESC: No	**Inventions/Patents:** No

B. ACCOMPLISHMENTS

B.1 WHAT ARE THE MAJOR GOALS OF THE PROJECT?

The project consists of two major goals, expressed as a set of specific aims:

Aim 1: Estimate the accuracy of automated video analysis for measuring human postures over time.

Aim 2: Compare measures of worker postures obtained using traditional video analysis techniques to those obtained using an automated video analysis system.

B.1.a Have the major goals changed since the initial competing award or previous report?

No

B.2 WHAT WAS ACCOMPLISHED UNDER THESE GOALS?

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B.3 COMPETITIVE REVISIONS/ADMINISTRATIVE SUPPLEMENTS

For this reporting period, is there one or more Revision/Supplement associated with this award for which reporting is required?

No

B.4 WHAT OPPORTUNITIES FOR TRAINING AND PROFESSIONAL DEVELOPMENT HAS THE PROJECT PROVIDED?

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B.5 HOW HAVE THE RESULTS BEEN DISSEMINATED TO COMMUNITIES OF INTEREST?

NOTHING TO REPORT

B.6 WHAT DO YOU PLAN TO DO DURING THE NEXT REPORTING PERIOD TO ACCOMPLISH THE GOALS?

Not Applicable

B.2: What did you accomplish under these goals?

Aim 1 Accomplishments: Laboratory-based data collection needed to accomplish Aim 1 was completed. We recruited 46 participants: 24 female (age: 31.5 ± 10.9 years; height: 164.0 ± 7.2 cm; body mass: 72.7 ± 15.8 kg) and 22 male (age: 34.8 ± 15.4 years; height: 179.0 ± 8.3 cm; body mass: 82.5 ± 15.1 kg).

The data collection procedures were designed as proposed in the application for funding and included two independent variables: i) posture variation (*high* or *low*) and ii) camera configuration (*2D single perspective*, *2D multi-perspective*, and *Kinect*). The experimental fixture was also constructed as proposed in the application for funding. However, several changes were made to the video recording hardware prior to the start of data collection. Most importantly, Microsoft discontinued support of its aging Kinect v2 depth camera proposed for use in the project prior to the start of data collection while other manufacturers released newer, suitable option. Ultimately, we selected the following:

1. Zed 2i (Sterelolabs Inc., San Francisco, CA): The Zed 2i includes two monocular cameras to achieve stereovision.
2. Realsense Depth Camera D455 (Intel Corporation, Santa Clara, CA): The Realsense D455 includes a monocular camera and a depth sensor (i.e., similar to the Kinect v2 originally proposed).

From these cameras, we were able to achieve 3D kinematic measurement using the proposed configurations in the following manner:

1. *2D single perspective:* using a single camera recording from the Zed 2i and Google's state-of-the-art MediaPipe human pose estimation algorithm (Alphabet Inc., Mountain View, CA) to predict the depth information needed for 3D measurement.
2. *2D multi-perspective:* using the stereovision recordings from the Zed 2i and Stereolabs' proprietary 3D human pose estimation algorithm; the Stereolabs algorithm uses the principles of triangulation.
3. *2D single perspective plus depth:* Essentially equivalent to the originally proposed Kinect v2 method, this configuration involves both the single camera and depth sensor recordings from the Intel Realsense camera; MediaPipe is used here, as well, but the depth information is based on the depth sensor recordings rather than predicted (in contrast to the *2D single perspective* configuration).

As proposed, the ground truth for estimating the accuracy of the computer vision-based kinematic measurement was optical motion capture. We used a 10-camera Optitrack (NaturalPoint, Corvallis, OR) for this purpose. Fifty reflective markers were used to provide 3D spatial position (i.e., X-Y-Z coordinates) of body landmarks needed to calculate angles of the neck, the dominant upper extremity (shoulder, elbow, wrist), the trunk, and the knees. All marker data have been processed (i.e., cleaned and filtered) and then imported into Visual3D (C-Motion, Germantown, MD) for calculating joint angles.

Analyses of data needed to finalize comparisons of the computer vision-based approaches and the ground truth motion capture data are ongoing. There are no results to report at this time (see *Discussion of Goals Not Met*, below).

Aim 2 accomplishments: We have finalized the pipeline for analyzing the existing workplace videos, which involves the following steps:

(1) extracting from the continuous video recordings segments associated with the specific work cycles analyzed using MVTA in the original study (an automated method to enhance efficiency has been completed);

(2) cropping the split-screen video segments into two separate videos, one for the sagittal plane view and one for the frontal plane view (complete);
(3) applying our computer vision and deep learning algorithms to generate kinematic information from the video segments (ongoing); and
(4) analyzing the kinematic information to produce summary measures consistent with those reported in the original study using MVTA (ongoing).

The original dataset included 1,098 existing workplace videos, recorded during a previous prospective study of physical risk factors and upper extremity musculoskeletal disorders. Processing of these videos and analyses of inter-method agreement between the MTVA approach and our automated video analysis approach are ongoing. There are no results to report at this time (see *Discussion of Goals Not Met*, below).

Discussion of Goals Not Met: The previous RPPR described administrative delays associated with co-Investigator Baek's move from the University of Iowa to the University of Virginia prior to the start of the project (i.e., 09/29/2021). At that time (March 2022), we were working through IRB details required before the University of Iowa's Division of Sponsored Programs could proceed with a subaward to the University of Virginia. We obtained the necessary IRB approval on 04/22/22 and the subaward itself was fully executed on 06/28/22, nine months after the project start date. While waiting for the subaward, personnel at the University of Iowa site continued preparations to commence data collection and analyses for both Aims 1 and 2. We hired additional personnel at both the University of Iowa and University of Virginia to accelerate project progress, with the overall goals of completing Aim 1 data collection and finalizing our approach to Aim 2 analyses by the end date of the award (09/29/23). These goals were achieved. Although the award has ended, work continues to finalize our analyses and we are committed to publishing project results.

Robust and Unbiased Results: We developed standard operating procedures and training for all personnel involved in the project. All experimental procedures were pilot tested. The experimental procedures remained as proposed in the application for funding, with well-defined and controlled independent variables, randomization of experimental conditions, a balanced study sample with respect gender, instrumentation calibration procedures specified, and well-defined a priori hypotheses to be tested among a study sample of justified size using appropriate statistical methods. Regular quality control checks were used to identify the presence of random and/or systematic bias. In addition, all key personnel on the project were required to report any conflicts of interest and, as needed, develop conflict of interest management plans in consultation with their University's conflict of interest in research offices.

B.4: What opportunities for training and professional development did the project provide?

While the research was not intended to provide training or professional development, several students have served as research assistants. At the University of Iowa, one PhD student (Tyler Guzowski, PhD 2025) and one MS student (Alexander Barnett, MS 2024) were employed on the project. Both are trainees of the Ergonomics Training Program within the NIOSH-funded Education and Research Center (ERC) at the University of Iowa (the Heartland Center for Occupational Health and Safety). As ERC trainees, these students have each completed an Individual Development Plan (IDP). The IDP provides trainees the opportunity to (1) engage in self-reflection of their academic and personal skills, strengths, and weaknesses, (2) identify desired skills and knowledge needed to achieve their goals, (3) determine areas that could benefit from targeted development, and then (4) establish an action plan to achieve both short and long-term goals. Short-term goals are typically directed toward academic performance and long-term goals typically reflect professional objectives. Each trainee prepares an IDP during their initial semester enrolled and then reviews it with their advisor. The IDP is a living document, and so trainees update the initial IDP at least once annually.

C. PRODUCTS

C.1 PUBLICATIONS

Are there publications or manuscripts accepted for publication in a journal or other publication (e.g., book, one-time publication, monograph) during the reporting period resulting directly from this award?

No

C.2 WEBSITE(S) OR OTHER INTERNET SITE(S)

NOTHING TO REPORT

C.3 TECHNOLOGIES OR TECHNIQUES

NOTHING TO REPORT

C.4 INVENTIONS, PATENT APPLICATIONS, AND/OR LICENSES

Have inventions, patent applications and/or licenses resulted from the award during the reporting period? No

If yes, has this information been previously provided to the PHS or to the official responsible for patent matters at the grantee organization? No

C.5 OTHER PRODUCTS AND RESOURCE SHARING

NOTHING TO REPORT

D. PARTICIPANTS

D.1 WHAT INDIVIDUALS HAVE WORKED ON THE PROJECT?

Commons ID	S/K	Name	Degree(s)	Role	Cal	Aca	Sum	Foreign Org	Country	SS
FETHKE	Y	Fethke, Nathan B	BS,MS,PHD	PD/PI	2.9	0.0	0.0			NA
FREDGERR	Y	Gerr, Fredric	MD,MPH,MD,MD,PHD	Co-Investigator	0.4	0.0	0.0			NA
JASONWANG	N	Wang, Jason		Graduate Student (research assistant)	9.0	0.0	0.0			NA
STEBAEK	Y	Baek, Stephen S	PhD	Co-Investigator	0.4	0.0	0.0			NA
TYLERGUZOWSKI	N	Guzowski, Tyler	BS,MS	Graduate Student (research assistant)	6.0	0.0	0.0			NA
ALBARNETT	N	Barnett, Alex Stephen	BA,MS	Hourly Student	2.9	0.0	0.0			NA
SHAHABAZARFAR	N	Azarfar, Shahab	PHD	Postdoctoral Scholar, Fellow, or Other Postdoctoral Position	4.0	0.0	0.0			NA
EPRESNALL	N	Presnall, Elizabeth M	BA,MPH	Staff Research Associate	1.6	0.0	0.0			NA
PHONGNGUYEN	N	Nguyen, Phong	DSC	Postdoctoral Scholar, Fellow, or Other Postdoctoral Position	3.0	0.0	0.0			NA
MOHAMMADISLAM23	N	Islam, Mohammad Shafkat	PHD	Postdoctoral Scholar, Fellow, or Other Postdoctoral Position	5.5	0.0	0.0			NA

Glossary of acronyms:
S/K - Senior/Key
Cal - Person Months (Calendar)
Aca - Person Months (Academic)
Sum - Person Months (Summer)
Foreign Org - Foreign Organization Affiliation
SS - Supplement Support
RS - Reentry Supplement
DS - Diversity Supplement
OT - Other
NA - Not Applicable

D.2 PERSONNEL UPDATES

D.2.a Level of Effort

Not Applicable
D.2.b New Senior/Key Personnel Not Applicable
D.2.c Changes in Other Support Not Applicable
D.2.d New Other Significant Contributors Not Applicable
D.2.e Multi-PI (MPI) Leadership Plan Not Applicable

E. IMPACT

E.1 WHAT IS THE IMPACT ON THE DEVELOPMENT OF HUMAN RESOURCES? Not Applicable
E.2 WHAT IS THE IMPACT ON PHYSICAL, INSTITUTIONAL, OR INFORMATION RESOURCES THAT FORM INFRASTRUCTURE? NOTHING TO REPORT
E.3 WHAT IS THE IMPACT ON TECHNOLOGY TRANSFER? Not Applicable
E.4 WHAT DOLLAR AMOUNT OF THE AWARD'S BUDGET IS BEING SPENT IN FOREIGN COUNTRY(IES)? NOTHING TO REPORT

G. SPECIAL REPORTING REQUIREMENTS SPECIAL REPORTING REQUIREMENTS

G.1 SPECIAL NOTICE OF AWARD TERMS AND FUNDING OPPORTUNITIES ANNOUNCEMENT REPORTING REQUIREMENTS

NOTHING TO REPORT

G.2 RESPONSIBLE CONDUCT OF RESEARCH

Not Applicable

G.3 MENTOR'S REPORT OR SPONSOR COMMENTS

Not Applicable

G.4 HUMAN SUBJECTS

G.4.a Does the project involve human subjects?

Not Applicable

G.4.b Inclusion Enrollment Data

File(s) uploaded:
Fethke R21_final cumulative enrollment.pdf

G.4.c ClinicalTrials.gov

Does this project include one or more applicable clinical trials that must be registered in ClinicalTrials.gov under FDAAA?

G.5 HUMAN SUBJECTS EDUCATION REQUIREMENT

NOT APPLICABLE

G.6 HUMAN EMBRYONIC STEM CELLS (HESCS)

Does this project involve human embryonic stem cells (only hESC lines listed as approved in the NIH Registry may be used in NIH funded research)?

No

G.7 VERTEBRATE ANIMALS

Not Applicable

G.8 PROJECT/PERFORMANCE SITES

Not Applicable

G.9 FOREIGN COMPONENT No foreign component
G.10 ESTIMATED UNOBLIGATED BALANCE Not Applicable
G.11 PROGRAM INCOME Not Applicable
G.12 F&A COSTS Not Applicable

Cumulative Inclusion Enrollment Report

This report format should NOT be used for collecting data from study participants.

Study Title: Using computer vision and deep learning to measure worker kinematics

Comments:

Racial Categories	Ethnic Categories									Total
	Not Hispanic or Latino			Hispanic or Latino			Unknown/Not Reported Ethnicity			
	Female	Male	Unknown/ Not Reported	Female	Male	Unknown/ Not Reported	Female	Male	Unknown/ Not Reported	
American Indian/ Alaska Native	0	0		0	0					**0**
Asian	4	1		0	0					**5**
Native Hawaiian or Other Pacific Islander	0	0		0	0					**0**
Black or African American	0	1		0	0					**1**
White	16	18		4	2					**40**
More Than One Race	0	0		0	0					**0**
Unknown or Not Reported	0	0	0	0	0					**0**
Total	**20**	**20**	**0**	**4**	**2**	**0**	**0**	**0**	**0**	**46**

I. OUTCOMES

I.1 What were the outcomes of the award?

Methods and procedures have been developed to enable robust validation of three-dimensional measurement of human posture and movement obtained from a combination of consumer-grade video recording devices, computer vision, and deep learning algorithms. The methods include consideration for the complexity of the video recording hardware (i.e., a single two-dimensional video, stereovision, or video plus depth sensing), all major body joints, and the extent of variation in joint angles over time (i.e., movement through small or large ranges of motion). While analyses are ongoing, results will provide occupational safety and health practitioners key information about the performance of computer vision-based task analysis and enterprise risk management applications (relative to ergonomics and musculoskeletal disorders) that have rapidly proliferated the marketplace.