

AWARD NUMBER: W81XWH-15-1-0445

TITLE: Automated Assessment of Postural Stability (AAPS)

PRINCIPAL INVESTIGATOR: Iyad Obeid, PhD

CONTRACTING ORGANIZATION: Temple University
1801 N Broad St
Philadelphia PA 19122

REPORT DATE: 14 October 2018

TYPE OF REPORT: Annual

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

DISTRIBUTION STATEMENT: Approved for Public Release;
Distribution Unlimited

The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision unless so designated by other documentation.

| REPORT DOCUMENTATION PAGE | | | | Form Approved OMB No. 0704-0188 | |
|---|--------------|--------------------------|----------------------------|---|---|
| Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS. | | | | | |
| 1. REPORT DATE 14 OCT 2018 | | 2. REPORT TYPE Annual | | 3. DATES COVERED 15 SEP 2017 – 14 SEP 2018 | |
| 4. TITLE AND SUBTITLE Automated Assessment of Postural Stability (AAPS) | | | | 5a. CONTRACT NUMBER W81XWH-15-1-0445 | |
| | | | | 5b. GRANT NUMBER | |
| | | | | 5c. PROGRAM ELEMENT NUMBER | |
| 6. AUTHOR(S) Iyad Obeid, PhD; Carole Tucker, PhD; Alessandro Napoli, PhD; Stephen Glass, PhD. E-Mail: iobeid@temple.edu | | | | 5d. PROJECT NUMBER | |
| | | | | 5e. TASK NUMBER | |
| | | | | 5f. WORK UNIT NUMBER | |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) TEMPLE UNIVERSITY-OF THE COMMONWEALTH SY 1801 N BROAD ST PHILADELPHIA PA 19122-6003 | | | | 8. PERFORMING ORGANIZATION REPORT NUMBER | |
| 9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army Medical Research and Materiel Command Fort Detrick, Maryland 21702-5012 | | | | 10. SPONSOR/MONITOR'S ACRONYM(S) | |
| | | | | 11. SPONSOR/MONITOR'S REPORT NUMBER(S) | |
| 12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for Public Release; Distribution Unlimited | | | | | |
| 13. SUPPLEMENTARY NOTES | | | | | |
| 14. ABSTRACT In Year 3, we have completed the AAPS (Aim 1), nearly completed data collection (Aim 2), and have field tested it extensively (Aim 3). We have also completed the xAAPS system (Aim 4) which adapts the AAPS into a kinetic movement and balance assessment tool. Both the AAPS and xAAPS are available as plug-and-play style Windows applications that require no specialized expertise to install and operate. Our signal processing algorithms have been revised and are now able to produce movement scores whose difference from those made by human observers are statistically negligible. Although the AAPS and xAAPS both encode specific balance assessments, the underlying software engine is easily adaptable for a wide range of other tests. | | | | | |
| 15. SUBJECT TERMS motion tracking, balance assessment, Microsoft Kinect, concussion assessment | | | | | |
| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | USAMRMC |
| Unclassified | Unclassified | Unclassified | Unclassified | 15 | 19b. TELEPHONE NUMBER (include area code) |

Table of Contents

| | |
|---|-----------|
| Introduction | 4 |
| Keywords | 4 |
| Accomplishments | 4 |
| Impact | 11 |
| Changes/Problems..... | 12 |
| Products | 13 |
| Participants & Other Collaborating Organizations | 13 |
| Special Reporting Requirements | 15 |
| Appendices | 15 |

Introduction

Keywords

motion tracking, balance assessment, Microsoft Kinect, concussion assessment

Accomplishments

What were the major goals and objectives of the project?

The purpose of this project is to create a portable system for assessing balance in armed forces personnel that can be administered in the field with minimal training. Although there are many reasons for assessing an individual's sense of balance, our project focuses on balance deficits caused by concussion, traumatic brain injury, and musculoskeletal injury, since these are especially relevant to fitness for duty. Our deliverable will be a stand-alone system comprising a Microsoft Kinect motion tracking system and a dedicated laptop personal computer running custom software for data acquisition and analysis. The system is called the Automated Assessment of Postural Stability, or AAPS.

The project is designed around four Specific Aims, or goals:

1. Develop Baseline AAPS System
2. AAPS Calibration and Baseline Evaluation
3. AAPS Field Evaluation
4. Develop Expanded xAAPS Test

What was accomplished under these goals?

Year 3 was devoted to optimizing performance of the AAPS system by improving the BESS error detection algorithm and the software graphical interfaces (GUI), as well as overall usability and experience. Substantial efforts were also dedicated to expanding the extended AAPS system capabilities and functionalities. Such an expansion has led to the creation of an xAAPS dedicated software suite and movement assessment algorithms. The xAAPS has been developed to automatically administer three dynamic balance trials that are based on modified versions of tests from the Functional Movement Screening (FMS) test, namely, Hurdle Step, In-line lunge and Deep Squat.

Accomplishment 1: AAPS Software Packaging and Distribution

The AAPS deliverable is a stand-alone system comprising a Microsoft Kinect motion tracking camera and a dedicated laptop running the AAPS software. In Year 3, the AAPS software has been completed and fully tested for static balance detection. In addition, the software graphical interfaces, as well as usability and user experience have been refined. Figure 1 shows the principle of operation of the AAPS system and its new and improved GUI with contextual user instructions.

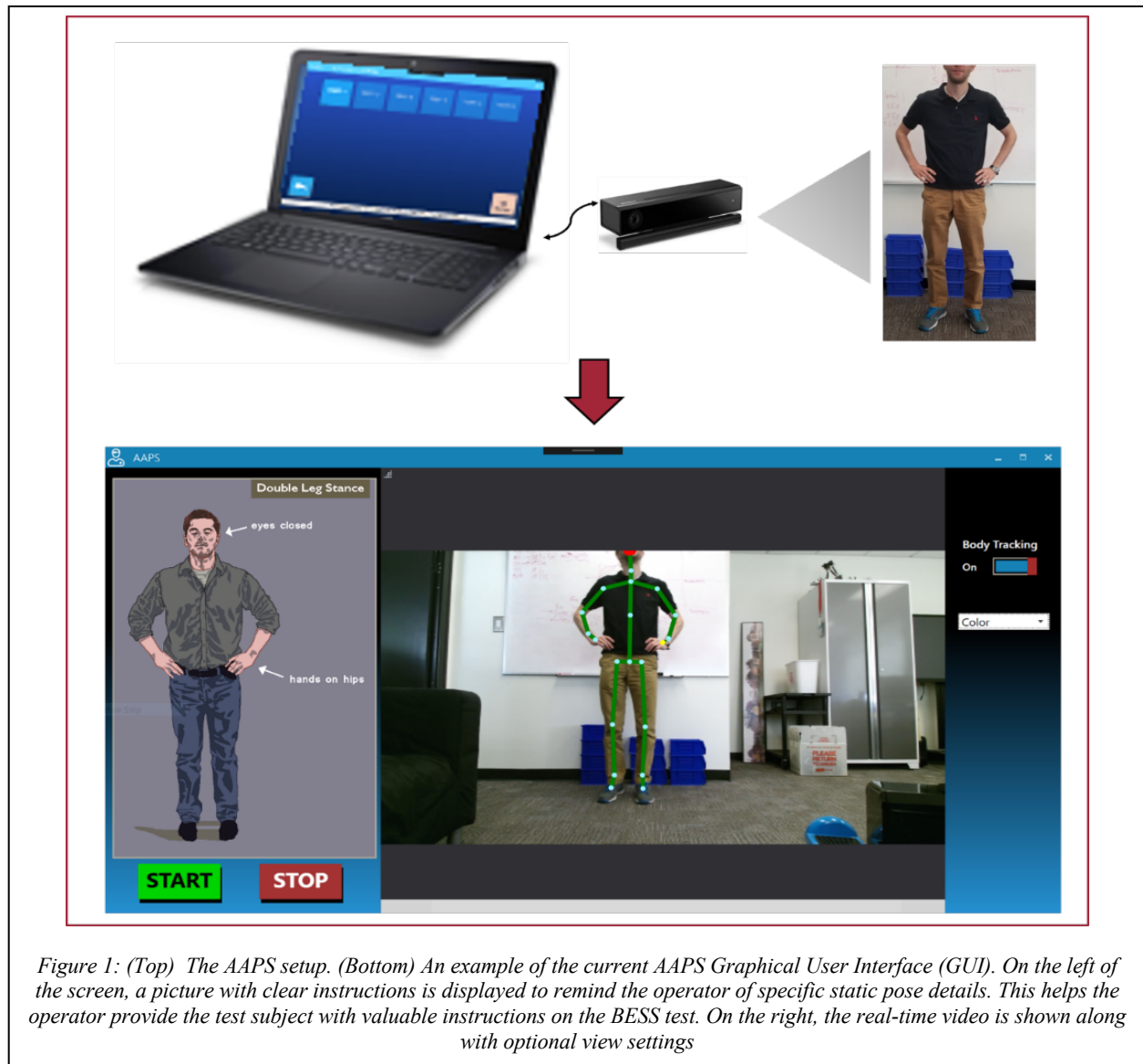


Figure 1: (Top) The AAPS setup. (Bottom) An example of the current AAPS Graphical User Interface (GUI). On the left of the screen, a picture with clear instructions is displayed to remind the operator of specific static pose details. This helps the operator provide the test subject with valuable instructions on the BESS test. On the right, the real-time video is shown along with optional view settings

Furthermore, to ensure compatibility with different Windows architectures and facilitate distribution to several users, the current version of the AAPS has been packaged into a single installation package. This allows the AAPS software to be installed with one click as a stand-alone Windows application that is compatible with any Windows 10 machine. In addition, all the necessary libraries and drivers have been packaged in the installation archive. The only additional required software consists of the Microsoft Kinect drivers that will need to be installed on the target computer to successfully use the Kinect device.

Accomplishment 2: The Expanded Automatic Assessment of Postural Stability (xAAPS)

The Expanded Automatic Assessment of Postural Stability deliverable is a stand-alone system comprising a Microsoft Kinect motion tracking camera and a dedicated laptop running the xAAPS software. A dedicated software suite has been designed and developed for the xAAPS. This software tool has been engineered to guide the test subject through all the necessary steps to perform three dynamic balance tests without the supervision of a clinical expert. In other words, the xAAPS can be used by a non-trained user as a result of the intuitive graphical interface and the presence of on-screen avatar that guides the subject

throughout the test execution. Figure 2 is a screenshot that shows the GUI and real-time operation of the xAAPS software.

The balance tests implemented in the xAAPS software are modified versions of the well-known Functional Movement Screening (FMS) test, namely a series of repetitions of the original FMS Hurdle Step, In-line lunge and deep squat.

After test completion, the subject's kinematic data are stored in dedicated files that can be analyzed off-line using a specifically designed machine learning approach. The movement analysis algorithms have been trained to provide movement quality scoring criteria that are similar to those assigned by the FMS test. Scoring is based on a scale from 1 to 3, where 1 indicates that the subject cannot perform the movement and 3 indicates perfect movement execution. Figure 3 shows a block diagram of the xAAPS FMS automatic scoring methods. Briefly, Kinect raw data are collected, and 3D body skeleton tracking coordinates are extracted in real-time. The extracted time series are re-sampled at a constant frequency of 30 fps and then low-pass filtered at 2Hz, using a 5th order low-pass Butterworth filter. Subsequently, two main kinematic metrics are derived for each trial, namely, the Center of Mass (COM) and the 3D joint displacement time series. The xAAPS scoring algorithm uses these metrics to carry out feature extraction and then classification. The extracted features were:

- COM Spectral Power
- COM Coefficient of Variation
- COM Continuous Phase Variability
- COM Dynamic Time Warping
- Principal Component Analysis (PCA) of 3D joint displacement

Finally, the above features were used to train a series of classification algorithms. We used a cross-validation approach with our dataset to evaluate classification performance. Our analysis indicated that Decision Tree, Support Vector Machine (SVM) and K-Nearest Neighbors (K-NN) were the algorithms with

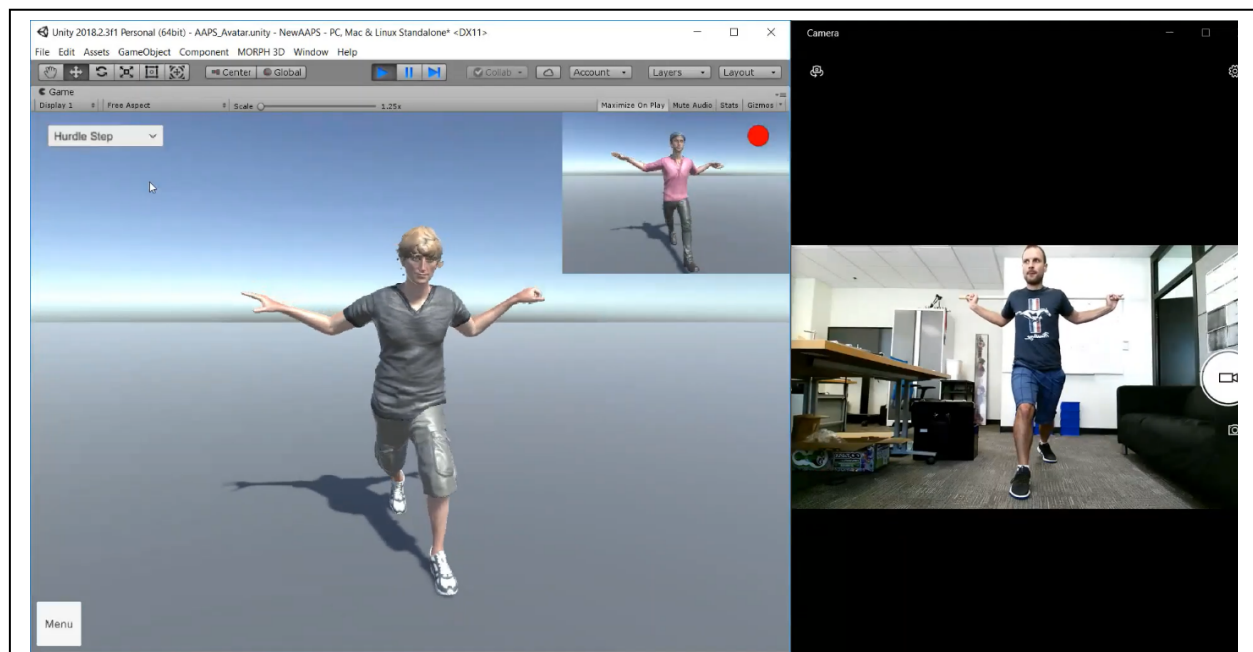
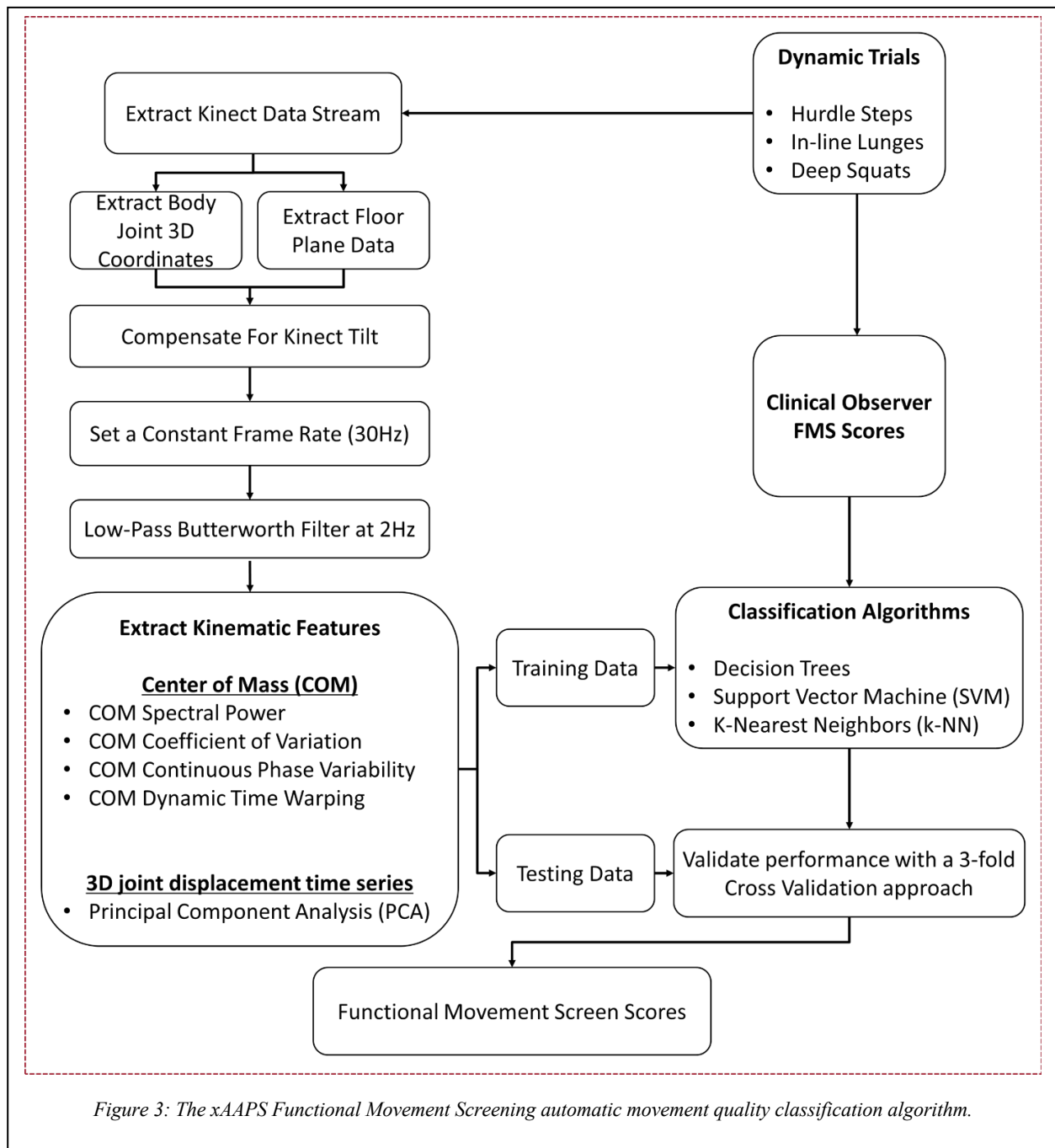


Figure 2: Example of the xAAPS dedicated software for data collection and automated scoring of three modified FMS dynamic tests.



the best classification performance for predicting FMS scores. The following section presents the xAAPS algorithms and performance in more detail. These results have also been presented at the 2018 Military Health System Research Symposium (MHSRS 2018), held in August 2018, in Kissimmee, FL.

The Expanded Automatic Assessment of Postural Stability (xAAPS)

Concussion is best detected when the evaluation of possible exposure is carried out in the field, at the earliest possible opportunity. The Balance Error Scoring System (BESS), which is a brief and easily administered test of static balance, has been devised to detect balance deficits, arising from concussion and

musculoskeletal injuries, in the field. The BESS presents four main limitations: 1) it requires the presence of a trained (clinical) observer to score the test; 2) the test-to-test reliability can be biased by the manual scoring system; 3) A visually scored test can result in under-reporting some of the symptoms; 4) The BESS test only measures static posture. To address these limitations, we have developed the Automated Assessment of Postural Stability (AAPS) system, that is an easy to set-up, computerized and quantitative system for automatically administering and scoring the BESS test in a wide variety of non-clinic locations using inexpensive off-the-shelf devices.

Furthermore, in order to provide a more comprehensive concussion evaluation tool we are developing the expanded AAPS (xAAPS) to introduce the evaluation of dynamic balance tasks. The xAAPS capability of evaluating coordinated dynamic movements will potentially provide more salient feedback for assessing concussion and suitability for return to duty than using static balance measures alone.

Methods

The xAAPS system consists of two hardware components: a Windows laptop and a Microsoft Kinect 2.0 device, paired with a custom-developed Windows software application. The xAAPS software has been designed and developed to be user-friendly and to guide the operator through all the necessary steps to correctly administer the testing protocols. At the end of each trial, the xAAPS automatically evaluates, displays and stores the balance scores in under a minute. The xAAPS features a custom developed balance evaluation method based on computer classification algorithms that convert the subject's three-dimensional joint center positions (as derived from the Kinect sensor) into balance metrics. These metrics are equivalent to Functional Movement Screening (FMS) scores assigned by an experienced observer. The FMS consists of seven movement patterns scored on a scale of 0-3 points, where 0 means pain and 3 a perfect execution. The current version of xAAPS focuses on continuous multi-repetition versions of the first three of the seven FMS assessments: Deep Squat (DS), Hurdle Step (HS) and In-line Lunge (ILL).

In order to validate the performance of the xAAPS scoring algorithm, we asked 26 young adults (12 male, 14 female) to perform the three FMS movements while their kinematic data were captured with the xAAPS system. To obtain reference data for comparison, video recordings of the movement tests were scored by an experienced observer. Those scores were then used as labels for the dataset when training the xAAPS classification algorithm.

More specifically, the xAAPS extracts 3D joint coordinates from the Kinect data stream. The Kinect generates these data at a variable sampling frequency, which is then resampled off-line to a constant rate of 30 fps. Subsequently, the resampled joint position time series are low-pass filtered with a fifth order Butterworth with cutoff frequency set at 2Hz to reduce measurement noise. The next step in the signal processing cascade is to extract features that can be successfully used to train a set of classification algorithms. For each trial, a total of 27 kinematic features are extracted and used to evaluate each trial quality. The extracted features range from commonly used kinematic metrics, such as range, mean and standard deviation of velocity, acceleration and jerk of the Center of Mass (COM) trajectory, to more complex features such as spectral power, coefficient of variation and continuous relative phase variability of the COM. Dynamic Time Warping (DTW) distances of COM and Principal Component Analysis (PCA) of the joint 3D displacement time series were also used as features. Next, we trained a set of gold-standard classification algorithms such as, Decision Trees, Support Vector Machine (SVM), k-Nearest Neighbors (k-NN) and Ensemble Bagged Trees. These classifiers' predictive performance was assessed using a 3-fold cross-validation approach. Finally, for each movement type, the optimal combination of features and classification algorithms were identified. A block diagram of the implemented signal processing is shown in Figure 3.

Results

The xAAPS can successfully score the three FMS movements (HS, ILL and DS), with scoring performance well above random classification levels, that given the distribution of our sample population, are 57.1%, 42.3% and 67.7%, respectively. Specifically, the xAAPS displayed the best scoring performance for DS trials, using an SVM classifier with a cross-validated prediction accuracy of 92.3%. The HS assessment accuracy was 84.6% using a Decision Tree algorithm and finally accuracy of 69.2% was measured for ILL using an Ensemble Bagged Tree approach (See Table 1). Furthermore, qualitative analysis of kinematic data time series, indicates that the xAAPS lower performance for ILL trials is due to larger inaccuracies of the Kinect body tracking algorithm when detecting the lower-extremity movements for ILL motion.

Conclusion

Our laboratory has recently shown that Kinect 2.0™ data is suitable for instrumenting simple field-expedient clinical static postural stability tests such as the BESS. With the present work, we present the xAAPS, an expanded version of the reliable and quantitative Automated Assessment of Postural Stability (AAPS). The statistical performance of the innovative xAAPS algorithms in predicting the human-assigned FMS scores for three movements, namely HS, ILL and DS, as performed by 26 subjects, shows that the xAAPS can be a valuable in-field expedient to evaluate dynamic balance, without the need of human scorers.

Furthermore, despite the current version of the system being optimized for three specific movements, the feature extraction and classification algorithms have been designed to be flexible, easily adjustable and re-trainable for the evaluation of further motion types and different clinical testing protocols.

Table 1: This Table summarizes the xAAPS capability of predicting FMS scores relative to the three tested movements for all the 26 collected subjects. xAAPS performance has been evaluated using a 3-Fold Cross-Validation approach on the entire dataset. The percentages represent the xAAPS capability of assigning a score that matches the one assigned by an experienced observer. The first entry of the Table reports the best performing classifiers for each movement category. The last row of the Table is the performance of a random classifier used here as a baseline for comparison. It can be noted that the three groups do not have a balanced probability distribution, in other words this data set presents an unbalanced classification problem.

| Cross-Validated xAAPS Performance | | | |
|-----------------------------------|----------------------|-----------------------|-------------------------------|
| Movement Type | Hurdle Steps | In-Line Lunges | Deep Squats |
| Best Performing Classifier | Course Decision Tree | Ensemble Bagged Trees | Linear Support Vector Machine |
| 3-Fold Cross-Validation Results | 84.6% | 69.2% | 92.3% |
| Random Classification Performance | 57.1% | 42.3% | 67.7% |

Progress Relative to Goals

Relative to our stated goals, the project is proceeding on schedule and on budget. As Table 2 shows, our progress is commensurate with the 36 months of effort we have made thus far. Aim 1 is essentially complete. Completion of Aim 2 only requires recruiting another 12 concussed male subjects; we have made plans to attend several contact sports tournaments in October and November and thus expect to meet this goal. In order to complete Aim 3, we are planning to do another round of field testing with our University's ROTC cadets. We have been in contact with the new ROTC director and we are scheduling two field-training events over the next 12 months. Finally, Aim 4 (xAAPS) requires evaluation of test data that has already been accomplished. These goals are all reasonably accomplished within the remaining 12-month timeframe. We have also allocated time to migrate the existing system to be sensor-agnostic, meaning that it will work with any depth camera, not just the Kinect. This is especially necessary since Microsoft is retiring the Kinect as a consumer product. Fortunately, numerous alternative sensors are now available off the shelf and it appears that integrating them into our system will be feasible. The remainder of our progress will be focused on publishing at least three more journal manuscripts which are currently in preparation.

From a budgetary perspective, the project is healthy. As of the end of Year 3 Quarter 4, we have spent \$1.236M. The expense breakdown is approximately 61% compensation expenses, 5% non-compensation expenses, and 35% indirect costs.

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

PIs Tucker and Obeid have been pro-active in supporting professional development of the students on the project. Postdocs Napoli and Glass have been delegated much of the day-to-day responsibility of executing the research on this project. We have sought to develop them across the board, and especially with

Table 2: Project status relative to timeline originally stated in the research proposal.

| Specific Aim 1 – Develop AAPS Baseline System | | |
|--|--------------|------|
| Port Image Processing Code to C/C++ | 1-5 months | 100% |
| Develop User Interface | 4-8 months | 100% |
| Develop AAPS for Field Use | 7-12 months | 100% |
| Specific Aim 2 – AAPS Calibration and Baseline Evaluation | | |
| Healthy Subject Evaluation | 12-18 months | 100% |
| Concussion Subject Evaluation | 18-30 months | 75% |
| Mild Musculoskeletal Injury Subject Evaluation | 18-30 months | 100% |
| Specific Aim 3 – AAPS Field Evaluation | | |
| Evaluate use by non-clinician operators | 12-15 months | 80% |
| Evaluate AAPS in Field Conditions | 14-24 months | 80% |
| Specific Aim 4 – Develop Expanded xAAPS Test | | |
| Determine movements for xAAPS test | 18-22 | 100% |
| Update AAPS software for xAAPS test | 18-30 | 100% |
| Evaluate xAAPS test | 30-36 | 80% |

manuscript preparation and grantsmanship, data analysis, and public presentations of their work. Dr. Glass accepted a full-time position as a research scientist at The University of Ohio where he began working in April. Dr. Napoli has accepted a full-time position as the lead engineer on a brain machine interface project at Jefferson University in Philadelphia and will start there when his responsibilities with the AAPS project are complete. Our graduate and undergraduate students have been similarly supported with respect to scientific writing, software development, scientific writing, and data collection.

How were the results disseminated to communities of interest?

We have disseminated our results through public talks, journal publications, and conference presentations (see the “Products” section below). We have been regular attendees at the MHSRS meeting in Orlando where we supplement our formal dissemination products with informal discussions with colleagues.

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

This coming year will be the final one of this project. We will complete all proposed tasks, and are on schedule to do so by Summer 2019.

Impact

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

One of the key impacts our work is having is that we are part of a community of researchers whose goal is to bring physical therapy testing out of the clinic and into the field. Through our work, we have engaged in this community, in conferences, through talks, through the peer-review process, and through informal conversations. For example, our research has enabled us to design even more ambitious human-performance tests in compact, field-deployable formats (proposals are currently in preparation and peer-review). Our work, especially in developing xAAPS through the Unity design engine, is leading to useful design insights that we will be sharing with the research community.

What was the impact on other disciplines?

Nothing to report.

What was the impact on technology transfer?

Nothing to report (yet).

What was the impact on society beyond science and technology?

Our goal has always been to create tools that allow the scientific community to better understand concussion and to help warfighters and athletes alike manage their concussive symptoms. Through our extensive data collection efforts, we have demonstrated the AAPS and xAAPS to several hundred individuals. Our observation has been that there is a great deal of enthusiasm for systems like ours that can be used to bring quantifiable performance results directly to the end-user as opposed to requiring a lab or clinic setting.

Changes/Problems

Changes in approach and reasons for change.

See below.

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

This year we have requested (and been granted) a no-cost extension for our work. Earlier in 2017 it was announced that Microsoft was discontinuing the Kinect as an off-the-shelf consumer product. This presented a challenge since we use Kinect as our input sensor. Fortunately, there are a number of equivalent 3D depth cameras available on the market now and we will be using our extended period of performance to evaluate those sensors and to build a sensor-agnostic interface to our system. Our initial work in this vein is positive; we are currently working with a device sold by Orbbec which appears to yield robust measurements across the board.

Changes that have a significant impact on expenditures.

Nothing to report.

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

Nothing to report.

Products

Published

Napoli, A., Glass, S. M., Tucker, C. A., & Obeid, I. (2018). The Expanded Automatic Assessment of Postural Stability: the xAAPS. In *Military Health System Research Symposium (MHSRS)*. Orlando, FL.

Glass, S. M., Napoli, A., Obeid, I., & Tucker, C. A. (2018). Effects of Concussion History on Center of Mass Motion During Modified Balance Error Scoring System (BESS) Testing in Women. In *Military Health System Research Symposium (MHSRS)*. Orlando, FL.

Glass, S. M., Napoli, A., Thompson, E. D., Obeid, I., & Tucker, C. A. (2018). Validity of an Automated Balance Error Scoring System. *Journal of Applied Biomechanics*, 1–16. <https://doi.org/10.1123/jab.2018-0056>

Glass, S. M., Napoli, A., Obeid, I., & Tucker, C. A. (2017). Inverse Kinematics Using Portable, Low-Cost Sensor Technology. In *Gait & Clinical Movement Analysis Society Annual Meeting*. Salt Lake City, UT.

Napoli, A., Glass, S., Ward, C., Tucker, C., & Obeid, I. (2017). Performance analysis of a generalized motion capture system using Microsoft Kinect 2.0. *Biomedical Signal Processing and Control*, 38, 265–280. <https://doi.org/10.1016/J.BSPC.2017.06.006>

Glass, S. M., Napoli, A., Obeid, I., & Tucker, C. (2017). Inverse Kinematics Using Portable, Low-Cost Sensor Technology. In *Proceedings of the Gait and Clinical Movement Analysis Society Annual Meeting*. Salt Lake City, UT.

Napoli, A., Glass, S. M., Tucker, C., & Obeid, I. (2017). The Automated Assessment of Postural Stability: Balance Detection Algorithm. *Annals of Biomedical Engineering*. <https://doi.org/10.1007/s10439-017-1911-8>

Napoli, A., Ward, C. R., Glass, S. M., Tucker, C., & Obeid, I. (2016). Automated Assessment of Postural Stability System. In *38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)* (pp. 6090–6093). IEEE. <https://doi.org/10.1109/EMBC.2016.7592118>

In Development

Glass, S. M., Napoli, A., Obeid, I., & Tucker, C. A. (TBD) Evaluation of Static and Dynamic Balance Outcomes Using Field-Expedient Methods

Napoli, A., Glass, S. M., Tucker, C. A., Obeid, I. (TBD) Design and Validation of a Dynamic Movement and Balance Assessment Tool

Napoli, A., Glass, S. M., Tucker, C. A., Obeid, I. (TBD) Predicting Concussion from Static Balance Assessment Data

Participants & Other Collaborating Organizations

What individuals have worked on the project?

Name: Iyad Obeid, PhD
Project Role: co-Principal Investigator
Identifier: <https://orcid.org/0000-0002-5796-843X>
Person-Months: 3
Contribution: Dr. Obeid contributed to project design and management, analyzed data, supervised data marshalling, wrote quarterly reports, and contributed to all technical publications.

Name: Carole Tucker, PhD
Project Role: co-Principal Investigator
Identifier: <https://orcid.org/0000-0002-9408-5898>
Person-Months: 3
Contribution: Dr. Tucker contributed to project design and management, IRB preparation, human subject protocol design, data collection, and analysis, and all technical publications.

Name: Alessandro Napoli
Project Role: Postdoctoral Fellow
Identifier: <https://orcid.org/0000-0002-4061-3747>
Person-Months: 12
Contribution: Was responsible for managing all aspects of the software organization and development and contributed heavily to actual software creation. He managed the graduate RAs and the undergraduates, contributed to data collection and analysis, and took a leading role on all technical publications.

Name: Stephen Glass
Project Role: Postdoctoral Fellow
Identifier: <https://orcid.org/0000-0001-6263-527X>
Person-Months: 7
Contribution: Was responsible for managing all aspects of data planning, collection and analysis, including IRB development. He managed junior students and took a leading role in all technical publications.

Name: Christian Ward
Project Role: Graduate Research Assistant
Identifier: <https://orcid.org/0000-0001-5394-8135>
Person-Months: 6
Contribution: Provided software development and data analytics support; contributed to management of undergraduate students.

Name: Nicholas Satterthwaite
Project Role: Graduate Researcher
Person-Months: 6
Contribution: Code development and documentation

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

Nothing to report.

What other organizations have been involved as partners?

Nothing to report.

Special Reporting Requirements

See Quad Chart in the Appendix

Appendices

Quad Chart – see next page

Automated Assessment of Postural Stability (AAPS)

Log Number: MR141272

Award Number: W81XWH-15-1-0445

PI: Ilyad Obeid & Carole A. Tucker

Org: Temple University

Award Amount: \$1.36M

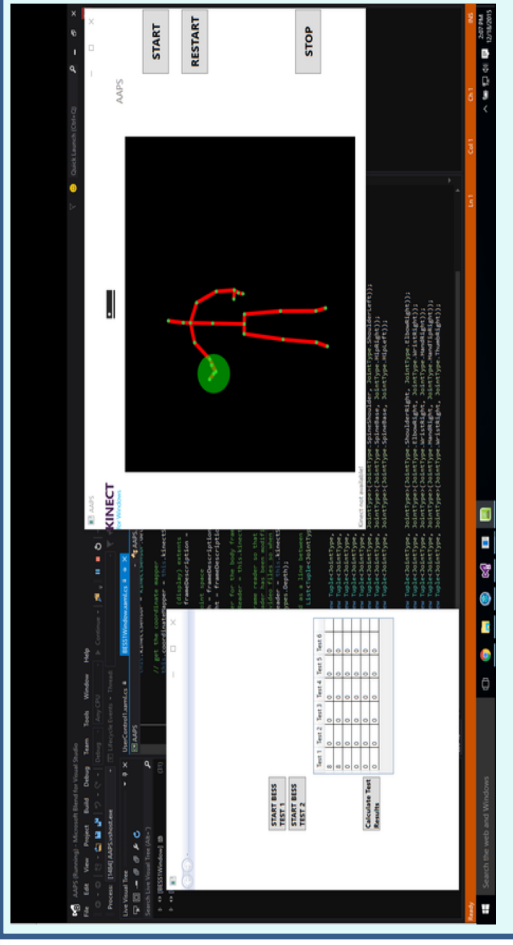


Study/Product Aim(s)

- Develop a fully functional proof-of-concept system (AAPS), featuring a complete software suite for automatically administering the Balance Error Scoring System (BESS) test.
- Calibrate the AAPS on healthy, concussion, and musculoskeletal injury subjects.
- Fully field test AAPS to ensure use by non-medical technicians.
- Expansion of AAPS to include dynamic postural tasks.

Approach

We aim to develop, calibrate, and field test a system for quantifying the impact postural and balance injuries using the Microsoft Kinect, an inexpensive motion capture system. The system will administer and score the BESS in field conditions without requiring a medically trained operator. We will expand the BESS to include dynamic tasks (lunge, squat, etc.) to better assess readiness for return to active military duty post mild TBI.



Screenshot showing development of C# code, prototype proof-of-concept GUI interface, and live image capture skeleton.

Goals/Milestones

- CY15 Goals** – System development
 - ✓ Port existing system from Matlab to C/C++ [100%]
 - ✓ Develop user interface for automatic test administration [100%]
- CY16 Goal** – Calibration and Field Testing
 - ✓ Determining reference scores for healthy, concussion, and musculoskeletal injury subjects [95%]
 - ✓ Comparing performance to gold standard benchmarks [90%]
 - ✓ Optimizing design for use by non-medical technicians [80%]
- CY17 Goal** – System expansion
 - ✓ Determining optimal dynamic tasks for assessment [100%]
 - ✓ Updating software to handle dynamic task tracking [100%]
- CY18 Goal** – System optimization
 - ✓ Complete expansion & optimize software via beta testing [80%]

Comments/Challenges/Issues/Concerns

- none

Budget Expenditure to Date

Projected Expenditure:

~\$1.360M

Actual Expenditure:

~\$1.236M

Timeline and Cost

| Activities | CY | 15 | 16 | 17 | 18 |
|--------------------------------|----|--------------|--------------|--------------|--------------|
| AAPS system development | | | | | |
| Calibrate AAPS (n=50 subjects) | | | | | |
| Field test AAPS | | | | | |
| Expand AAPS – Dynamic tasks | | | | | |
| Estimated Budget (\$k) | | \$200 | \$500 | \$500 | \$200 |

Updated: 11 October 2018