The OpenBiomechanics Project

The Open Source Initiative for Anonymized, Elite-Level Athletic Motion Capture Data

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Abstract

Interest in quantifying human movement, particularly in elite sport, increases with each passing year. However, analysis of sport biomechanics data has traditionally been restricted to academic laboratories and professional sport organizations. A public sport biomechanics resource would democratize access to human movement data and accelerate progress and innovation for the sport biomechanics field as a whole. In this paper, we introduce ***The OpenBiomechanics Project***, an initiative started by ***Driveline Baseball Research & Development*** to provide free, elite-level, research grade motion capture data to the general public for independent individual exploration and analysis. We begin by providing raw and processed data from a sample of 100 baseball pitchers. We then discuss future directions within baseball, expansion to other sports and athletic movements, and outline supporting documentation and additional resources.

1 Introduction

Open access resources exist in other biomechanics sub disciplines [3, 5].

2 Data collection

Data collection took place at Driveline Baseball in Kent, Washington, USA as part of each athlete's motion capture assessment. After a standardized warm up consisting of static and dynamic stretching, resistance band exercises, and preparatory throwing drills, we applied between 45 and 48 reflective markers directly to the athlete's skin over relevant bony landmarks (Table **??**). We then allowed athletes to complete a final warm up consisting of preparatory throws from the pitching mound. Once the athlete indicated they felt ready to throw with game-like effort, we recorded up to five fastball pitches from a pitching mound at a regulation distance (18.4 m).

Although athletes were cued to throw at the provided strike zone, we did not require athletes to throw a strike for a trial to be considered valid. We considered a trial valid if all reflective markers remained affixed to the athlete throughout the pitching motion. Pitch velocities were measured to the nearest tenth of a mile per hour using a radar gun positioned behind home plate and paired with each trial prior to processing and analysis.

Marker positions were recorded at 360 Hz by fourteen cameras (Prime 17W; Optitrack/NaturalPoint Inc., Corvallis, OR, USA) while ground reaction force data were collected at 1,080 Hz by three force plates embedded in a custom concrete mound (1 x FP4080-15-TM-2000, 2 x FP9090-15-TM-2000; Bertec Corp., Columbus, OH, USA). Kinematic and kinetic data were synchronized using Optitrack's Motive software. Once we collected a sufficient number of pitches (typically between three and five trials), C3D files were exported for processing in Visual3D and Python.

3 Data processing

C3D files meeting the validity criteria were exported from Motive. Where necessary, we used cubic spline and pattern-based gap filling techniques prior to export to interpolate occluded marker positions. C3D files were then fed into a custom Visual3D processing pipeline for pose estimation and inverse dynamics calculations.

3.1 Linked-Segment Model

Our full-body skeletal model consisted of 14 body segments [bilateral feet (1-2), shanks (3-4), thighs (5-6), upper arms (7-8), forearms (9-10), and hands (11-12), plus a pelvis (13) and thorax (14)] separated into four inverse dynamics linkages representing the four limbs of the body. The pelvis and thorax were left unconstrained (6 DOF) with respect to the linkages and with respect to each other.

We used default Visual3D segment mass/body mass ratios, inertial parameters, and segment geometries [4, 6]. The hip joint centers and pelvis segment were modeled using Bell's CODA methods [1, 2]. Joint centers for the elbows, wrists, knees, and ankles were defined as the midpoint between the joint's medial and lateral markers. Shoulder joint centers were offset relative to the acromion markers [7]. Complete model specifications may be found in the .MDH file provided in the ***OBP GitHub repository***.

4 How to Use

Data for the OpenBiomechanics Project may be found in our GitHub repository linked previously in this article. Although single-use downloads are possible, we recommend familiarizing yourself with the source control program *git*, if you are not already. Using *git* best practices ensures that your data and code remain updated in the event of any patches, changes, or new releases. For most users, the application ***GitHub Desktop*** will suffice, and comes with supporting tutorials and documentation.

Once you have GitHub desktop (or an analogous *git* solution) in place, simply fork our repository to create your own branch from which you can customize our code and analyze our data. Any changes or additions you commit will remain on your branch, allowing all users to perform their own analyses without interference from other researchers.

4.1 Terms of Use

Data and code provided through the OpenBiomechanics project are protected under a Creative Commons license and free for individual use. Researchers

4.2 Naming Conventions

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4.3 Fileshare and GitHub Repository

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4.4 Citing and Contributing

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5 Future Directions

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6 Additional Resources

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Abbreviation	Rigid Body	Description
C7	Thorax	Seventh cervical vertebrae
CLAV	Thorax	Jugular notch
LANK	Left shank, left foot	Left ankle lateral malleolus
LASI	Pelvis	Left anterior superior iliac spine
LBAK[a]	Thorax	Left scapular inferior angle
LBHD	Head	Left, posterior
LELB	Left upper arm, left forearm	Left lateral humeral epicondyle
LFHD	Head	Left, anterior
LFIN	Left hand	Third metacarpophalangeal joint
LFRM	Left forearm	Left forearm
LHEE	Left foot	Heel
LIC[a]	Pelvis	Left iliac crest
LKNE	Left thigh, left shank	Left lateral femoral condyle
LMANK	Left shank, left foot	Left ankle medial malleolus
LMELB	Left upper arm, left forearm	Left medial humeral epicondyle
LMKNE	Left thigh, left shank	Left medial femoral condyle
LPSI	Pelvis	Left posterior superior iliac spine
LSHO	Left upper arm	Left acromial plateau
LTHI	Left thigh	Left thigh
LTIB	Left shank	Left shank
LTOE	Left foot	Left second metatarsophalangeal joint
LUPA	Left upper arm	Left upper arm
LWRA	Left forearm, left hand	Left radial styloid
LWRB	Left forearm, left hand	Left ulnar styloid
RANK	Right shank, right foot	Right ankle lateral malleolus
RASI	Pelvis	Right anterior superior iliac spine
RBAK	Thorax	Right scapular inferior angle
RBHD	Head	Right, posterior
RELB	Right upper arm, right forearm	Right lateral humeral epicondyle
RFHD	Head	Right, anterior
RFIN	Right hand	Third metacarpophalangeal joint
RFRM	Right forearm	Right forearm
RHEE	Right foot	Right heel
RIC[a]	Pelvis	Right iliac crest
RKNE	Right thigh, right shank	Right lateral femoral condyle
RMANK	Right shank, right foot	Right ankle medial malleolus
RMELB	Right upper arm, right forearm	Right medial humeral epicondyle
RMKNE	Right thigh, right shank	Right medial femoral condyle
RPSI	Pelvis	Right posterior superior iliac spine
RSHO	Right upper arm	Right acromial plateau
RTHI	Right thigh	Right thigh
RTIB	Right shank	Right shank
RTOE	Right foot	Right second metatarsophalangeal joint
RUPA	Right upper arm	Right upper arm
RWRA	Right forearm, right hand	Right radial styloid
RWRB	Right forearm, right hand	Right ulnar styloid
STRN	Thorax	Xiphoid Process
T10	Thorax	Tenth thoracic vertebrae

[a] Left back and iliac crest markers were removed from our marker set in 2021. Therefore, LBAK/LIC/RIC markers may not be present in all C3D files