THE UNIVERSITY of TENNESSEE CHATTANOOGA

RELIABILITY AND VALIDITY OF TRAZER FOR ANALYZING GLOBAL LINEAR KINEMATICS

Nichol SL, Badger SG, Hogg JA

DISCLOSURE

- ☐ Nichol and Badger have nothing to disclose
- ☐ TRAZER consulted with Hogg to establish reliability and validity of global kinematics

BACKGROUND

- 3-D motion capture is the gold standard for examining functional movement to predict propensity for injury[1-4]
  - Limitations: expensive, difficult to operate, requires space[2,5]
- 2-D motion capture is comparable to the gold standard for the sagittal plane, but not in the frontal or transverse planes[3,4]
- Establishing reliability and validity of a 2-D motion capture system would allow for more routine functional assessment

TRAZER

- TRAZER might be a viable option as a surrogate for a 3-D motion capture system in the clinical setting
- A 2-D motion capture system designed to produce valid kinematics of performance tests with respect to the x, y, and z coordinate planes[6]
- Measures total distance traveled, average speed, average acceleration, average deceleration, and and reaction time

RELIABILITY OF GLOBAL KINEMATICS

- Total distance, average reaction time, and average velocity have shown reliable intraclass correlation coefficient values (ICCs) ranging from 0.66-0.86[7]
- A previous version of this unit has been established for reliability, so it is being replicated due to an updated software on TRAZER that needs investigation[8]
  - ICCs ranged from 0.65-0.95 with the exception of average reaction time, average deceleration, and maximum acceleration

VALIDITY OF GLOBAL KINEMATICS

- A previous validation of TRAZER yielded mixed agreement with 3-D motion capture found mixed results for validity[8]
  - Total distance ICC: 0.79
  - Maximum velocity ICC: 0.08
  - Maximum acceleration ICC: 0.01
- A white paper yielded more divergent results:[6]
  - Total distance ICC range: 0.93-0.99
  - Average velocity ICC range: 0.93-0.99
  - Average acceleration ICC range: 0.83-0.96
  - Average deceleration ICC range: 0.90-0.97
- A previous version of this unit has been validated, so it is being replicated due to an updated software on TRAZER that needs investigation[8]

PURPOSE STATEMENT

- To establish the reliability of the TRAZER system when assessing the global linear motions of total distance, average speed, average acceleration, average deceleration, and average reaction time.

- To establish validity of TRAZER compared to VICON when assessing the global linear motions of total distance, average speed, average acceleration, and average deceleration.

STUDY DESIGN

- Purpose 1: two session within-subject design with sessions separated by at least 48 hours

- Purpose 2: one session within-subject design; with each participant being measured simultaneously by 2-D and 3-D motion capture systems
  - The first session was used primarily for this purpose; if the data were inconclusive, the second session was used to capture validity

PARTICIPANTS

- Demographics:
  - 23.72 ± 2.35 yrs
  - 166 ± 6.68 cm
  - 77 ± 24.59 kg
  - Males: 4
  - Females: 14
- Inclusion Criteria
  - At least 18 years old
- Exclusion Criteria
  - Over the age of 30
  - Lower extremity injury in the last 6 mo.
- Written informed consent was obtained (UTHSC IRB: 23-09650-XP)

METHODS - RELIABILITY

- Warm-up (10-minutes)
  - 5-minute bike
  - TRAZER program run through (2-3 mins)

- Participants' acceleration, deceleration, reaction time, and distance traveled were captured using TRAZER
  - TRAZER Protocol: React Multidirectional $x32$

- Methods were carried out twice, separated by at least 48 hours

METHODS - RELIABILITY

TRAZER

- ☐ Set up in center of VICON cameras
- ☐ 32 football tackling buoys in 8 positions

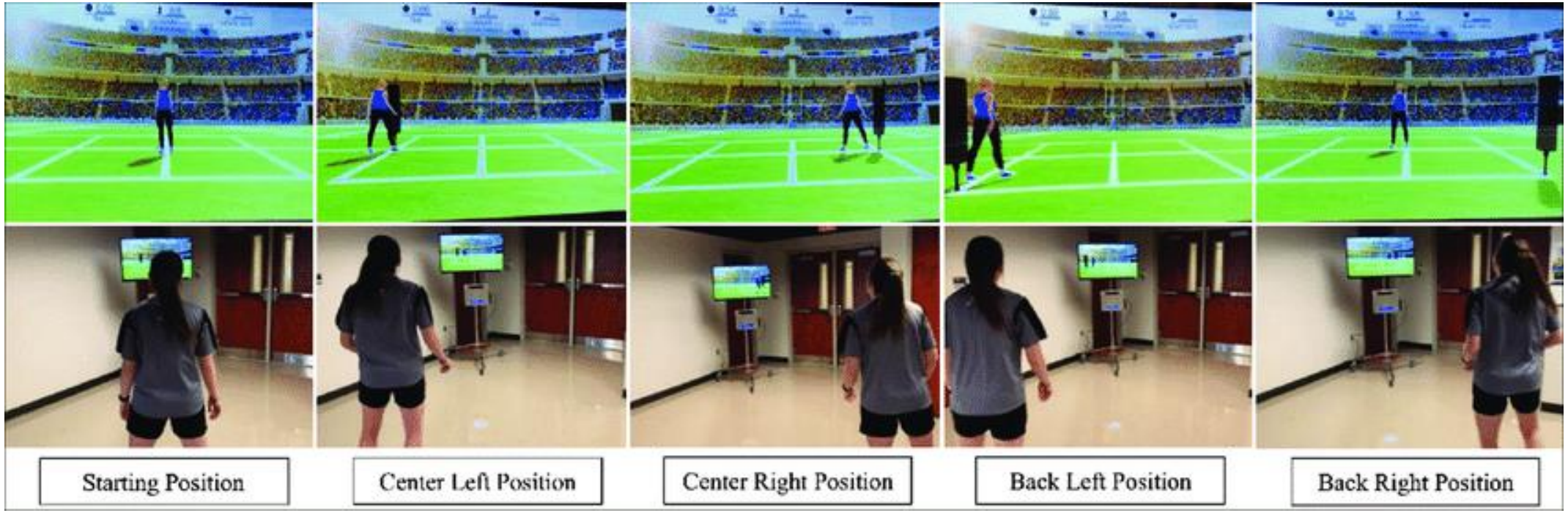


Fig. 1: Depiction of TRAZER Protocol. Hogg JA, Carlson LM, Rogers A, Briles MW, Acocello SN, Wilkerson GB. Reliability and concurrent validity of TRAZER compared to three-dimensional motion capture. *JCTRES*. 2021;7(1):100-107, PMID: 34104813.

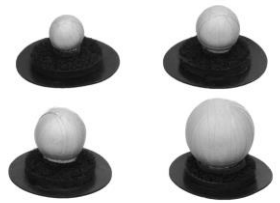
METHODS - VALIDITY

Eight VICON motion capture cameras were calibrated to allow for sampling at 100Hz in a 1.75 x 1.75 m capture area that corresponded with the TRAZER capture area.

METHODS - VALIDITY

- Patient set-up:
  - A retroreflective marker was placed on the spinous process of the L5 vertebra that was located through palpation.
  - Reflective jewelry was removed and reflective surfaces of the participant's clothes and shoes were covered with athletic tape to limit artifacts.

- Validity was assessed concurrently with the first reliability trial. If the data were corrupt, the procedures were repeated with the second reliability trial.



VARIABLES DEFINED

- **Total Distance (m)**: cumulative distance traveled[7,9]
- **Average Speed/Velocity (m/s)**: the average meters per second of dynamic movement in each direction.[7]
- **Average Acceleration (m/s^2)**: an *increase* in velocity divided by time within the measured frames[9]
- **Average Deceleration (m/s^2)**: a *decrease* in velocity divided by time within the measured frames[9]
- **Reaction Time (s)**: the time it takes between stimulus onset and the participant movement of 20 cm in the correct direction[7, 9]

DATA HANDLING

- TRAZER metrics obtained by tracking “base of the spine”
- Vicon data obtained using raw coordinates from digitized L5 spinous process marker
- Raw marker coordinate data were interpolated & filtered with a 12 Hz low-pass 4th order Butterworth filter
- Data were processed in R using the packages “signal”, “imputeTS”, “zoo”, & “purr”.
- Validity: 3-D variables were computed to correspond with TRAZER variables

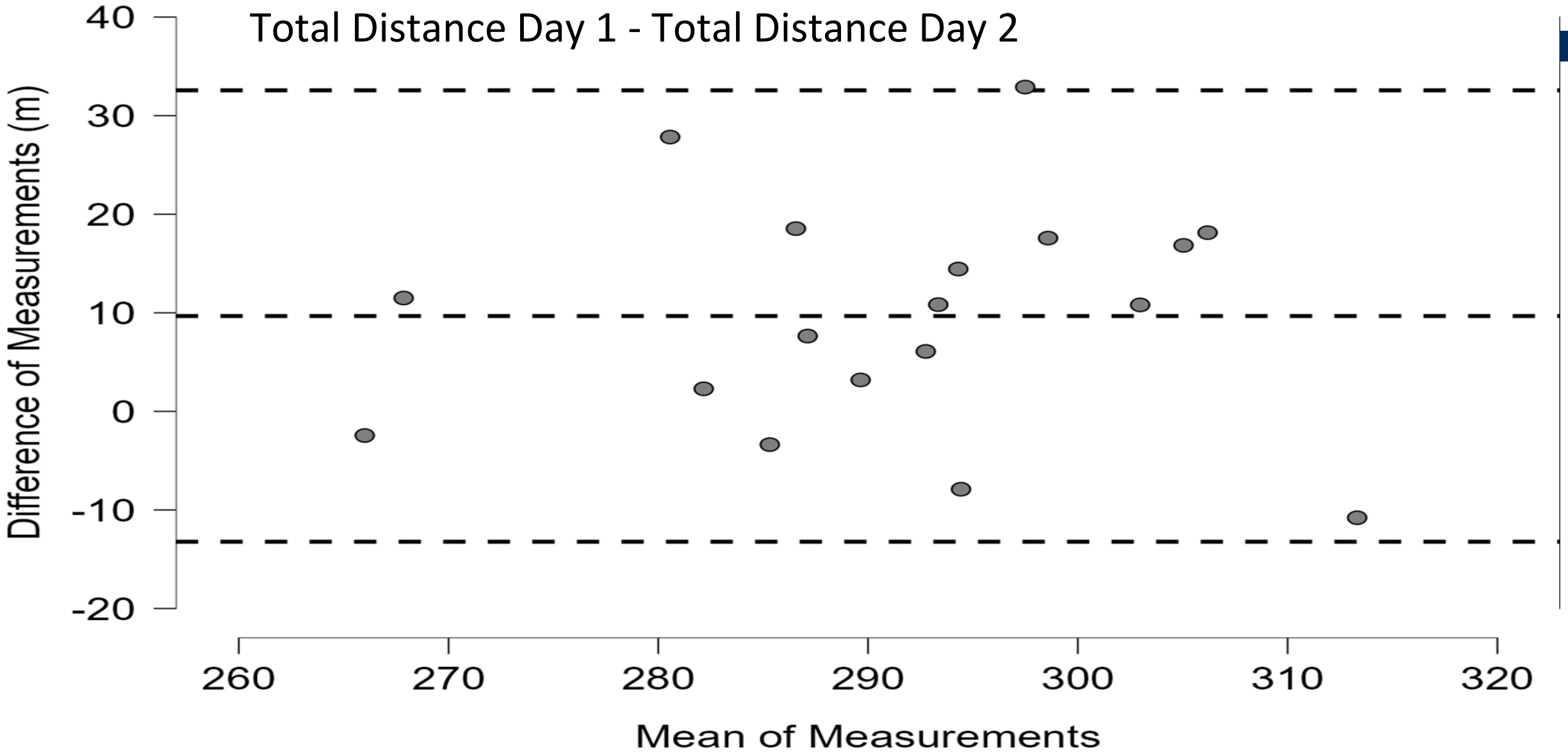
Statistical Analysis

- Data were analyzed through ICCs and Bland Altman Plots using JASP[10]
- ICC values were interpreted as follows:[11]
  - Poor: <0.5
  - Moderate: 0.5-0.75
  - Good: 0.75-0.9
  - Excellent: >0.9
- $ICC_{3,k}$ type was used because we wanted to inspect two-way mixed effects consistency with multiple raters and measurements[11]

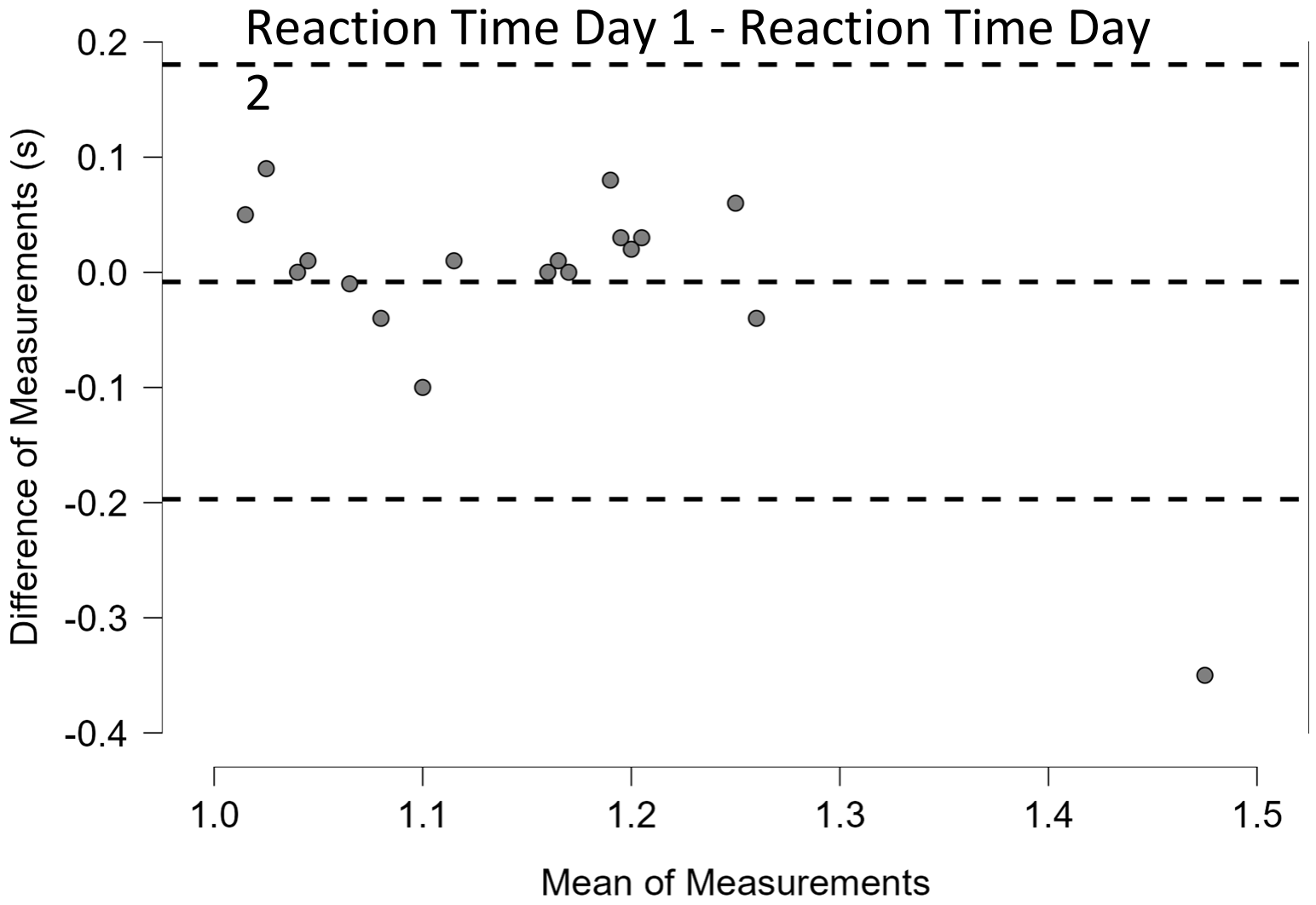
RELIABILITY - INTRACLASS CORRELATION

Variables	ICC (95% CI)
Total Distance (m)	0.778 (0.407, 0.917)
Average Velocity (m/s)	**0.921** (0.789, 0.971)
Average Acceleration (m/s^2)	**0.932** (0.819, 0.975)
Average Deceleration (m/s^2)	**0.937** (0.831, 0.976)
Reaction Time (s)	0.822 (0.532, 0.933)

RELIABILITY - BLAND ALTMAN PLOTS



RELIABILITY - BLAND ALTMAN PLOTS

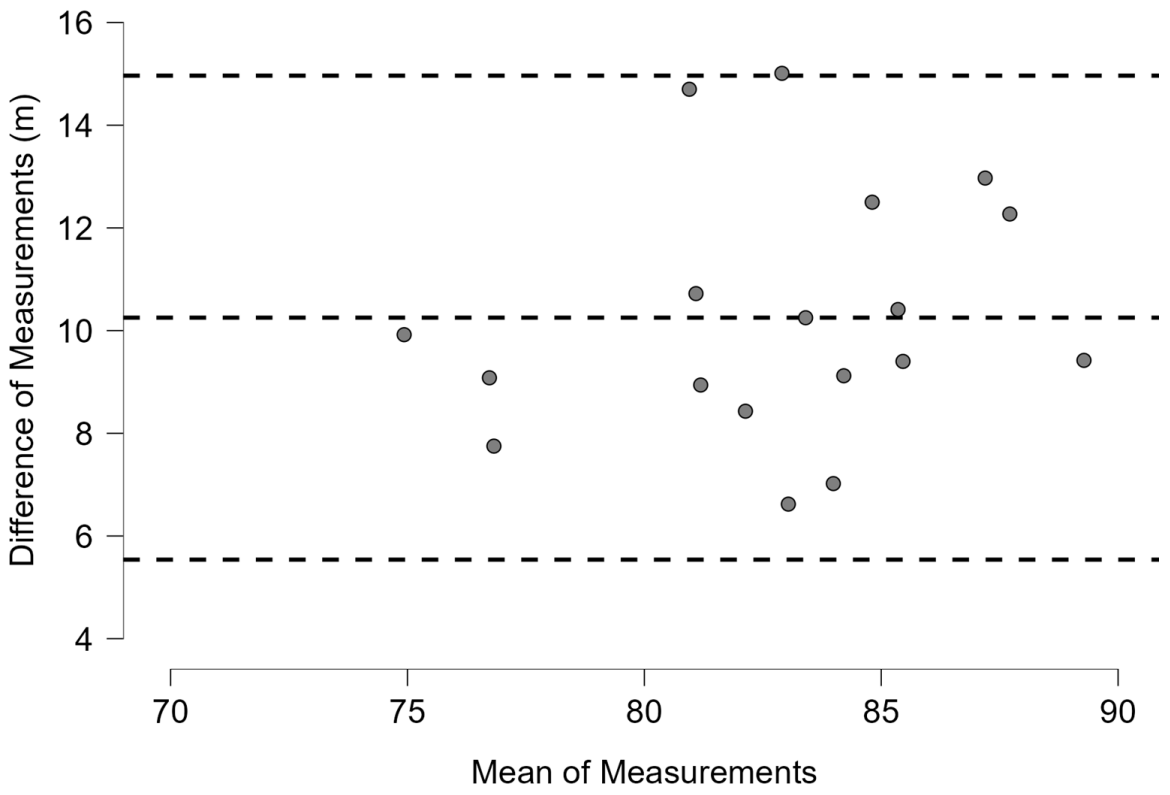


VALIDITY - INTRACLASS CORRELATION

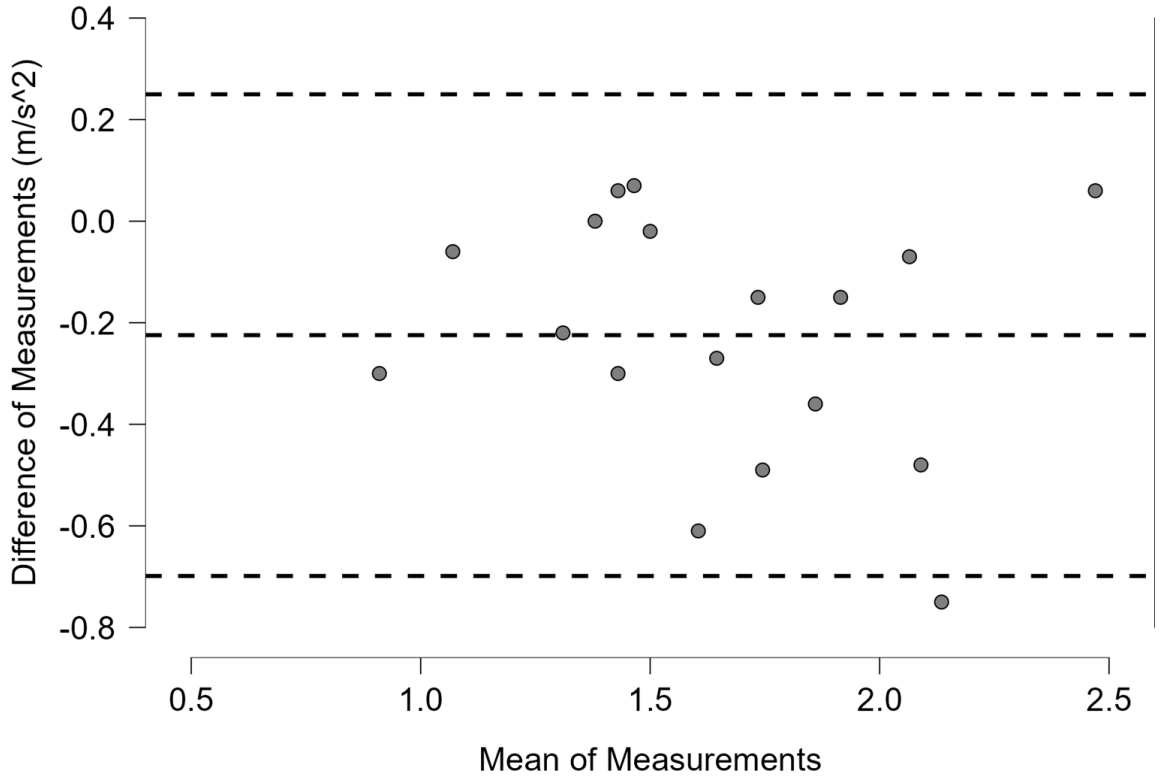
Variables	ICC (95% CI)
Total Distance (m)	**0.902** (0.738, 0.963)
Average Speed (m/s)	**0.911** (0.761, 0.967)
Average Acceleration (m/s^2)	**0.933** (0.820, 0.975)
Average Deceleration (m/s^2)	**0.905** (0.747, 0.965)

VALIDITY - BLAND ALTMAN PLOTS

TRAZER Total Distance - VICON Total Distance

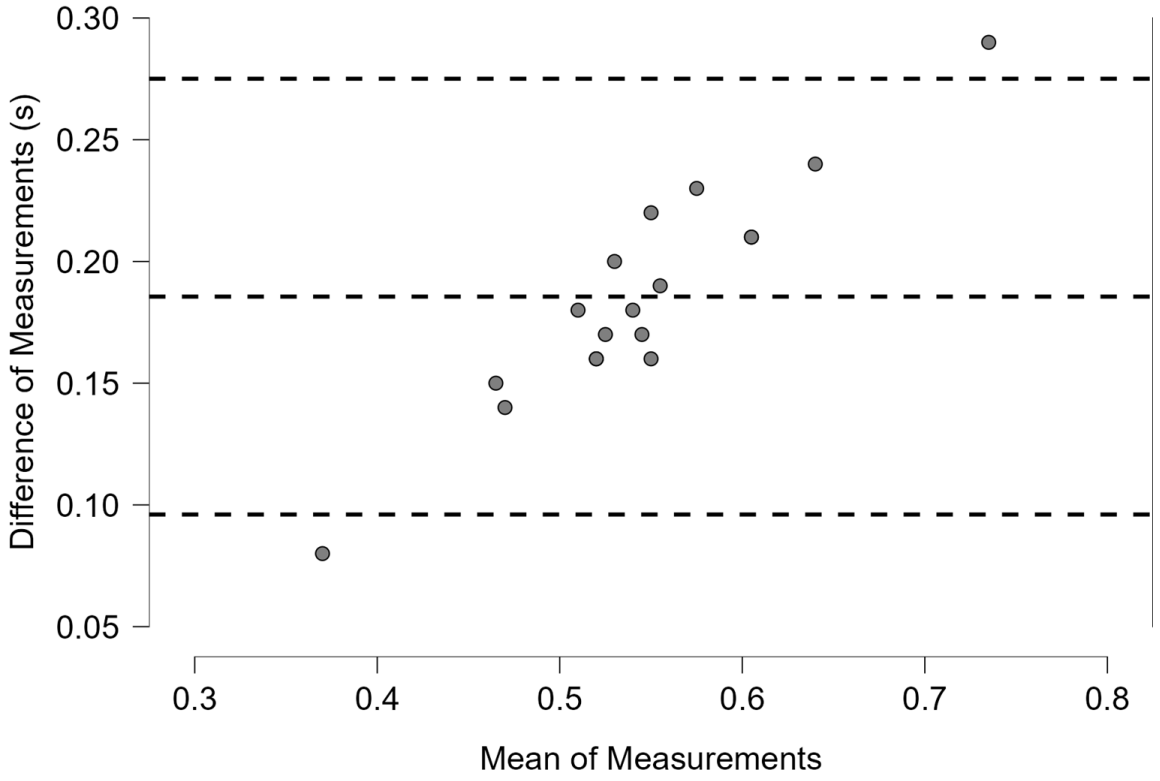


TRAZER Deceleration - VICON Deceleration

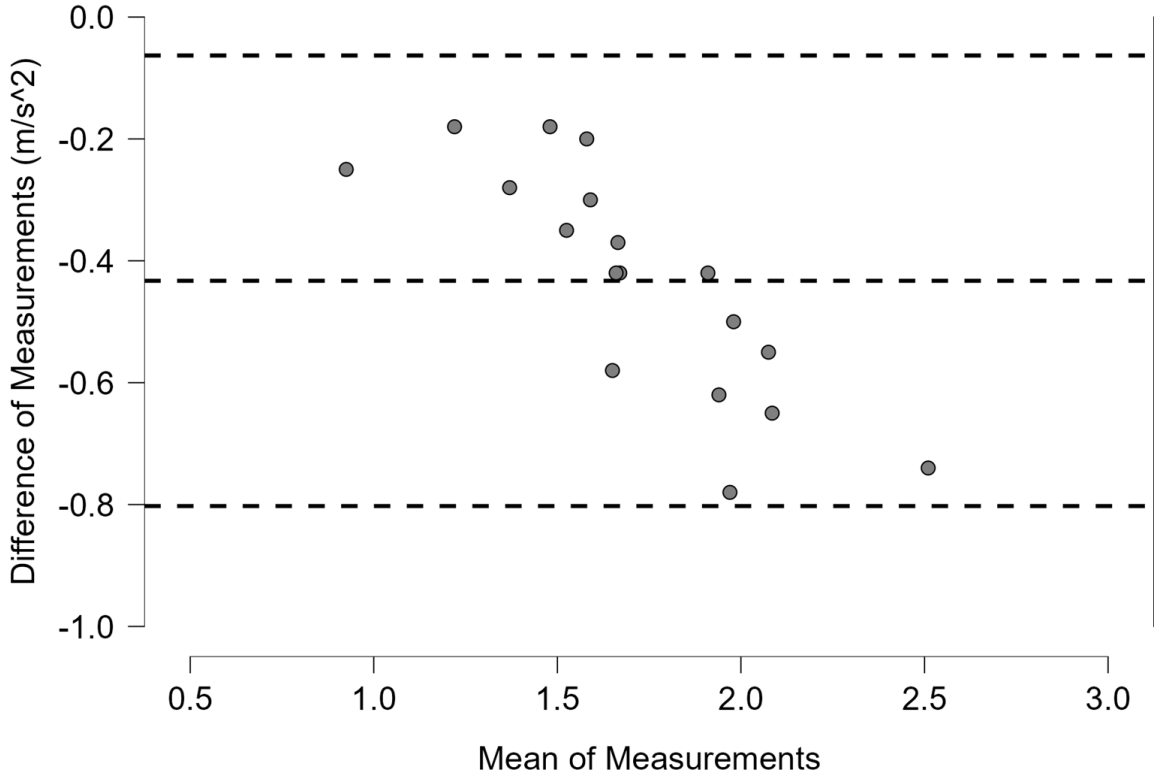


VALIDITY - BLAND ALTMAN PLOTS

TRAZER Speed - VICON Speed

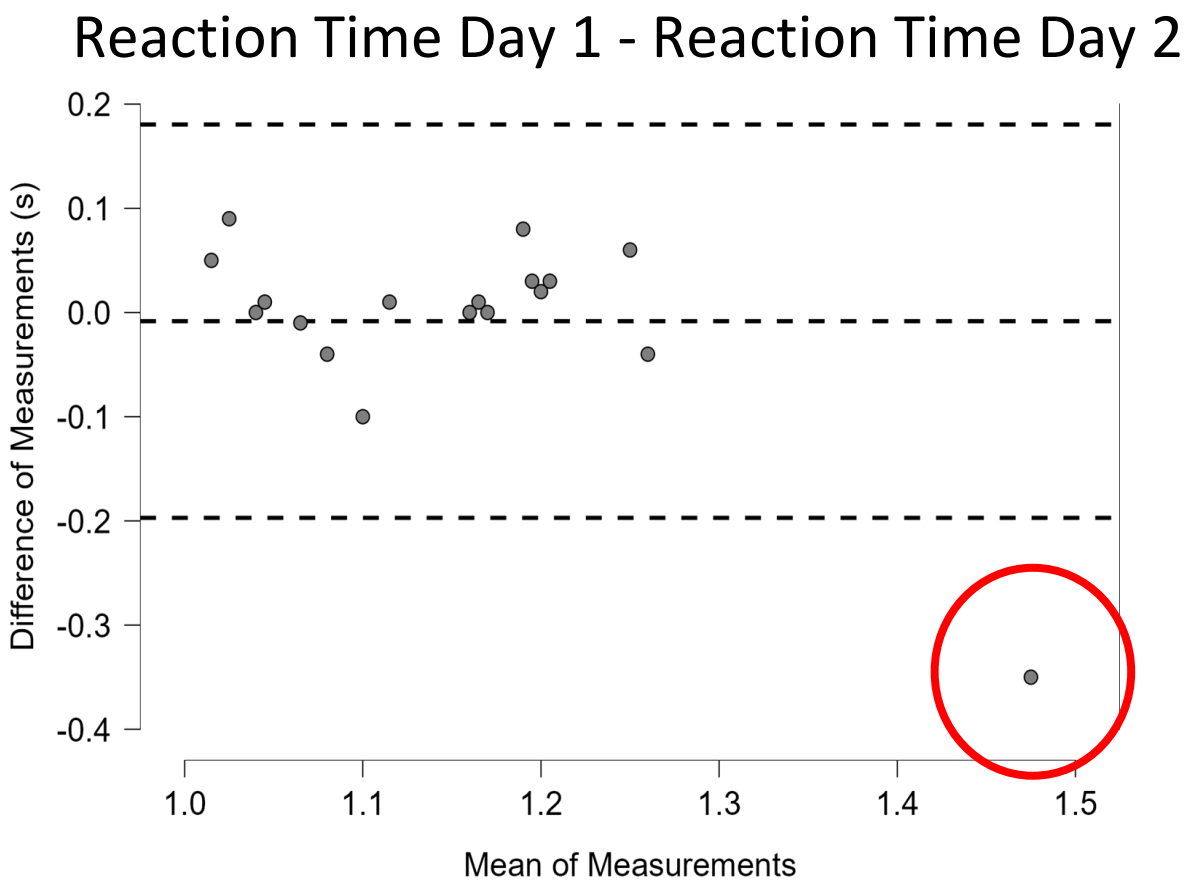


TRAZER Acceleration - VICON Acceleration



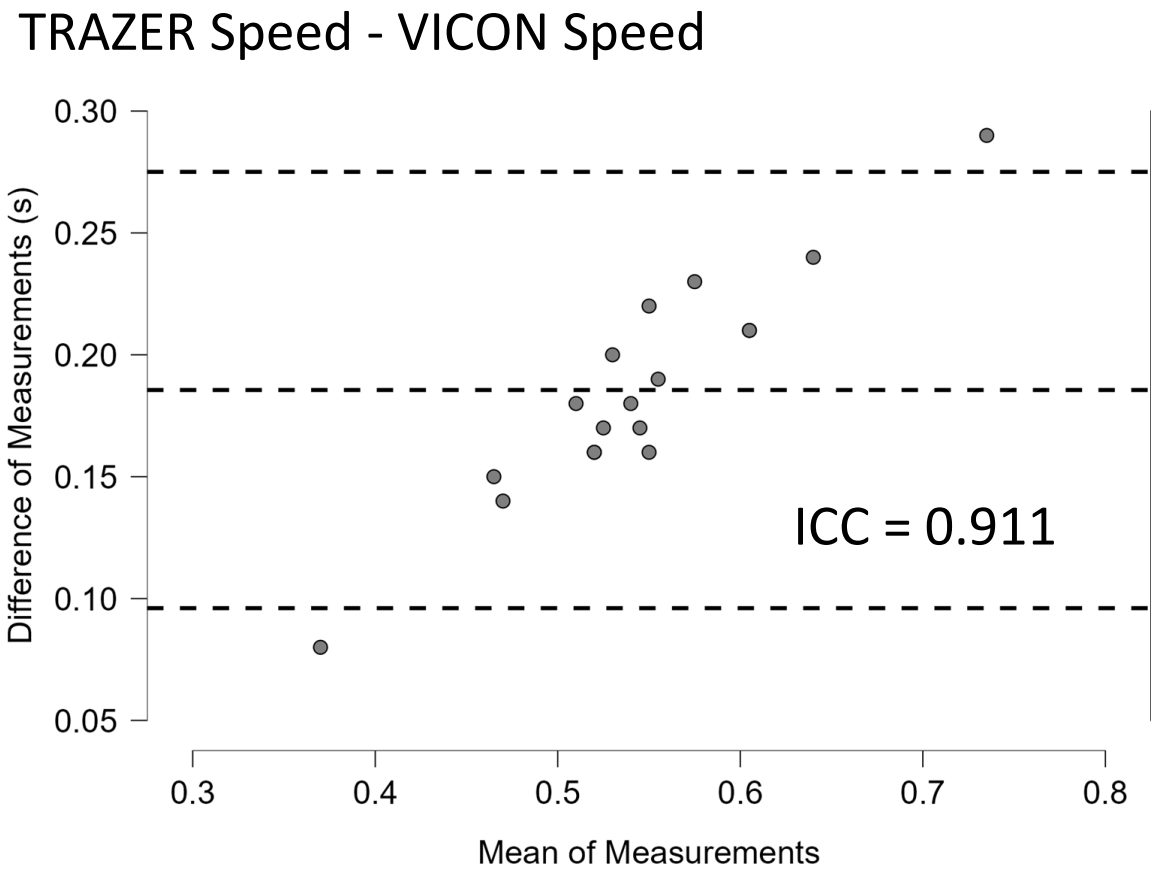
DISCUSSION - RELIABILITY

- **Excellent** test-retest reliability by TRAZER for acceleration, velocity, and deceleration
- **Good** test-retest reliability for total distance and reaction time
- Non-normal data could potentially be due to lack of effort on the second trial by one participant



DISCUSSION - VALIDITY

- **Excellent** between-system validity across all measures
- TRAZER underestimates acceleration measurements, but overestimates speed measurements
  - More accurate when mean is closer to zero (heteroskedastic)
- Despite this Bland-Altman, the ICC is 0.911



CLINICAL RELEVANCE

- Our study showed the latest version of TRAZER is a reliable and valid alternative to the gold standard 3-D motion capture when measuring linear kinematics
- Using TRAZER as a means to assess performance is a more viable option than the gold standard[1-5]
  - Less training
  - Less space
  - Less finances
- Future research should examine specific joint angle measurements to determine injury susceptibility that TRAZER may be more valuable for predicting

REFERENCES

1. Eltoukhy M, Kuenze C, Oh J, Apanovitch E, Butler L, Signorile JF. Concurrent validity of depth-sensing cameras for noncontact ACL injury screening during side-cut maneuvers in adolescent athletes: a preliminary study. *J. Appl. Biomech*. 2019;35:2–10.
2. Eltoukhy MA, Kuenze C, Oh J, Signorile JF. Validation of static and dynamic balance assessment using microsoft kinect for young and elderly populations. *IEEE J. Biomed. Health Inform*. 2018;22:147–53.
3. Mauntel TC, Cameron KL, Piestrosimone B, Marshall SW, Hackney AC, Padua DA. Validation of a commercially available markerless motion-capture system for trunk and lower extremity kinematics during a jump-landing assessment. *J. Athl. Train*. 2021;56(2):177-190, doi 10.4085/1062-6050-0023.20.
4. Ford KR, Myer GD, Hewett TE. Reliability of landing 3D motion analysis: implications for longitudinal analyses. *Med Sci Sports Exerc*. 2007;39:2021–8.
5. Schmitz A, Ye M, Boggess G, Shapiro R, Yang R, Noehren B. The measurement of in vivo joint angles during a squat using a single camera markerless motion capture system as compared to a marker based system. Gait Posture. 2015;41(2):694-698. doi:10.1016/j.gaitpost.2015.01.028
6. Nyman E. A Comprehensive Evaluation of the TRAZER System:Verification and Validation of Measurement Constructs. 2017
7. Reynolds FR. Reliability and Precision of Measurements Derived from the CYBEX TRAZER[Master's Thesis]. The University of Tennessee at Chattanooga; 2006.
8. Hogg JA, Carlson LM, Rogers A, Briles MW, Acocello SN, Wilkerson GB. Reliability and concurrent validity of TRAZER compared to three-dimensional motion capture. *JCTRES*. 2021;7(1):100-107, PMID: 34104813.
9. Romance A. Product Manager. TRAZER. 2024.
10. JASP Team (2024). JASP (Version 0.19.3)[Computer software].
11. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J Chiropr Med*. 2017;16(4):346. doi: 10.1016/j.jcm.2017.10.001.

QUESTIONS?