Kinetisense Risk of Fall Assessment

Ryan Comeau BSc, DC, ACC
Adam Luchkanych MSc. Kin
Jenelle Cousins BSc. Kin, P. Kin
Benjamin Croon BSc. Kin

The Problem:

Falls and fall-related injuries are a leading cause of mortality in the elderly population(1,2). Falls are the second leading cause of unintentional injury deaths worldwide, with an estimated 684, 000 individuals dying from fall-related injury each year(3). Fall-related injuries represent a major public health concern and are associated with a high financial burden on the health care system(3). It has been estimated that 30% of persons over 65 years of age and 50% of persons over 80 years of age will experience at least one fall each year(4). One major consequence of falls in the elderly is hip fracture, with falls being associated with over 90% of all hip fractures(5,6). All-cause mortality is increased among hip fracture patients compared to healthy individuals of the same age(7). As such, the World Health Organization (WHO) identifies falls in the elderly population as an epidemic and considers the proper assessment and correction to be crucial(3). With the elderly population expanding in the coming years, the extent of this public health problem will only grow unless steps are made to address this concern(8).

Owing to its present and growing health concern, considerable research has explored the topic of risk of fall. Many of these studies have centered around the assessment of gait(9–11). Specifically, researchers have explored how individual gait characteristics differ between young and old, and fallers and non-fallers(12–14). Gait characteristics such as speed, stride length, and time spent in double support have emerged from this body of work as reliable factors associated with the risk of fall(9,11,14–16). Older individuals are known to have decreased gait speed and stride length compared to a younger cohort(13). This has been attributed, in part, to a reduction in hip extension in the elderly population which is partially compensated for by an increase in anterior pelvic tilt(12). Further, it has been suggested that gait speeds of less than 0.77m/s represent an independent risk marker for recurrent falls(17). Stride length can be a differential marker between fallers and non-fallers within the elderly population(9,18,19). During walking, older individuals have been found to spend more time in double leg support when compared to younger persons(20). This has been proven as another risk of fall marker and can be used to differentiate between fallers and non-fallers in the elderly population(14). This increase in time spent in double-leg support is thought to be a gait strategy employed by elderly individuals to assist in maintaining their dynamic balance and stabilize their inefficient gait control(10,14).

Balance and gait impairments increase the risk of fall in older persons and represent another independent predictor of a standardized quality of life estimate(21,22). Beyond the impact of dynamic balance, static balance has been proven reliable in assessing risk of fall(23). An analysis of the Functional Gait Assessment found that participants who had less postural sway during static balance performed better on the assessment which represents a decreased risk of fall(23). The aging process affects men and women differently with women performing better on standing balance on foam with eyes open and closed, and in tandem stance(24). This indicates a potential need to consider biological sex in risk of fall assessments; however, further research is still required. Balance and gait characteristics are intrinsically linked to lower extremity strength and power and should therefore be considered in the assessment of risk of fall(25).

Lower extremity strength and power constitute another crucial factor in risk of fall assessments in the elderly(26). Exercise programs that are aerobic in nature and increase leg strength have been shown to increase gait speed in the elderly which is directly tied to risk of fall(27,28). Improvements in lower limb strength also correlate with improved performance on static balance assessments(26). The five-times sit-to-stand (5x STS) test is a proven and reliable assessment of lower extremity strength and power in risk of

fall in the elderly(29). Specifically, the 5x STS has benefits over a longer 30s sit-to-stand test when assessing clinical populations(30). Similar to balance, deficits in lower extremity strength are associated with decreased performance on the Functional Gait Assessment and increased risk of fall(23).

In line with the risk of fall algorithm outlined by the US Centers for Disease Control and Prevention (CDC), and following the parameters outlined above, the need for objective, reliable, and clinically applicable methods for the identification of elderly individuals at high risk of fall is crucial(31). This is crucial to the health and survival of the individual. Many of the current methods of assessing risk of fall heavily rely on subjective measures which detract from the inter- and intra-examiner reliability. Early detection facilitates implementation of preventative interventions. With such measures in place, the risk of fall could be addressed before a costly fall takes place. Effective identification of the risk of fall in the elderly population is essential for preventing injury, extending health-span, and reducing the risk of death.

The Solution:

Kinetisense® has created a novel markerless motion capture system that utilizes a custom and proprietary human tracking SDK. With the creation of an Artificial Intelligence (AI) and machine learning human tracking system called the "Kinetisense MoCap Engine". The MoCap engine utilizes advanced joint tracking capabilities and removes outlier data in real time. Using an Intel Realsense 3D depth sensor or the LiDAR sensor contained within the iPad Pro camera (4th Generation or newer), Kinetisense® has created an accurate, depth sensing technology with the ability to track all three planes of human movement.

Kinetisense's "risk of fall" module analyzes multiple gait parameters that have been found to be indicative of functionality and subsequently one's risk of fall. The portable system consists of either a laptop and Intel Realsense 415 sensor (fig. 1), or an iPad (fig. 2), each paired with the Kinetisense software.

The proprietary algorithms of Kinetisense® increase the accuracy of motion capture over that of the Microsoft Kinect SDK, allowing for accurate joint identification and biomechanical analysis in the frontal, sagittal and transverse planes. Kinetisense® has extended the accuracy of the Kinect SDK in the following way:

1. The use of tri-planar depth/infrared data to enhance the tracking accuracy of joints by greater than 30% accuracy as compared to the Microsoft Kinect 2 sensor/SDK.
2. Increased frame speed capture to a constant 90 frames per second versus the 15-30 frames per second of the Microsoft Kinect 2 sensor/SDK.
3. The proprietary Kinetisense® "Motion Capture Engine", which removes "outlier" biomechanical data in real time.
4. Advanced Artificial Intelligence (AI) provides enhanced joint location and movement tracking accuracy.
5. The use of a LiDAR sensor equipped within Apple's iPad Pro creates an even more portable human tracking system.

Kinetisense® has been designed to provide an affordable means of acquiring 3D joint, posture and balance analysis. The Kinetisense® software provides real-time analysis and easy to understand reporting for motion capture in all planes of movement. The real-time representation of human motion data and the increased inter- and intra-examiner

reliability in assessment separates Kinetisense® from other analysis tools. The 3D capture of joint and body position replaces the need for wearable sensors that lack efficiency and are difficult to place on the body. Wearable sensor placement is often not reproducible between sessions, thus affecting the reliability of assessment.

Clinical Applications:

1. Risk of Fall Assessment Baseline The system should be used for all patients over the age of 65 to assess the risk of fall and determine if the patient requires intervention such as therapy, environmental modifications or assisted living.

2. Triaging for the Level of Assisted Care The data provided by the system can give valuable insight into the level of assisted living that is required for the individual and the respective timelines of these living modifications.

3. Trend Data of Functional Improvement/Regression The system provides valuable historical data over multiple assessments of the individual's improvement or decline in function, as well as the rate of functional change over time.

4. Fitting of Assisted Walking Device Such as a "Walker" or a "Cane" The system provides information on compensatory movement patterns, and which assisted aids will create a more symmetric gait pattern.

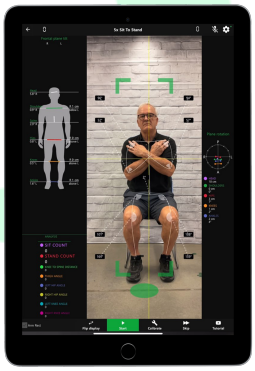
5. Addition of Ototoxic Medication or Multiple Medication (prescription) There are numerous commonly prescribed medications that are "ototoxic" and affect proprioception and balance. Taking more than 5 prescription medications (even non-ototoxic) is seen as an increased risk factor for geriatric falls.

The System:

Fig 1.

The Kinetisense® Desktop paired with the Intel Realsense 415 camera and Kinetisense technology. Allowing for the accurate joint and axis motion analysis of the body by acquiring data in the frontal, sagittal and transverse plane. This data is acquired without the use of wearable sensors and with a single front facing Intel Realsense sensor.

Fig 2.



The Kinetisense® technology uses the LiDAR sensor equipped within the iPad Pro (4th Generation or newer). Allowing for the accurate joint and axis motion analysis of the body by acquiring data in the frontal, sagittal and transverse plane. This data is acquired without the use of wearable sensors and with a single front facing Intel Realsense sensor.

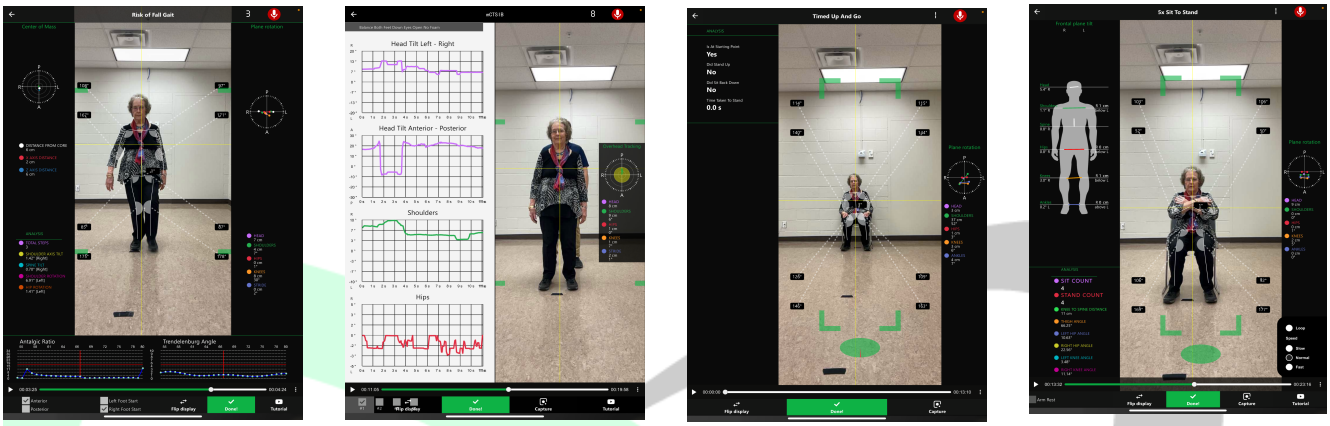


Fig 3.

Kinetisense® *uses all four assessments in a Risk of Fall workflow based off the CDC Risk of Fall Parameters. The use of Kinetisense risk of fall gait systems analyzes biomechanics and displays data in real-time. Four different assessments are conducted: Risk of Fall Gait, mCTSIB (balance), Timed Up and Go, and 5 x Sit to Stand.*

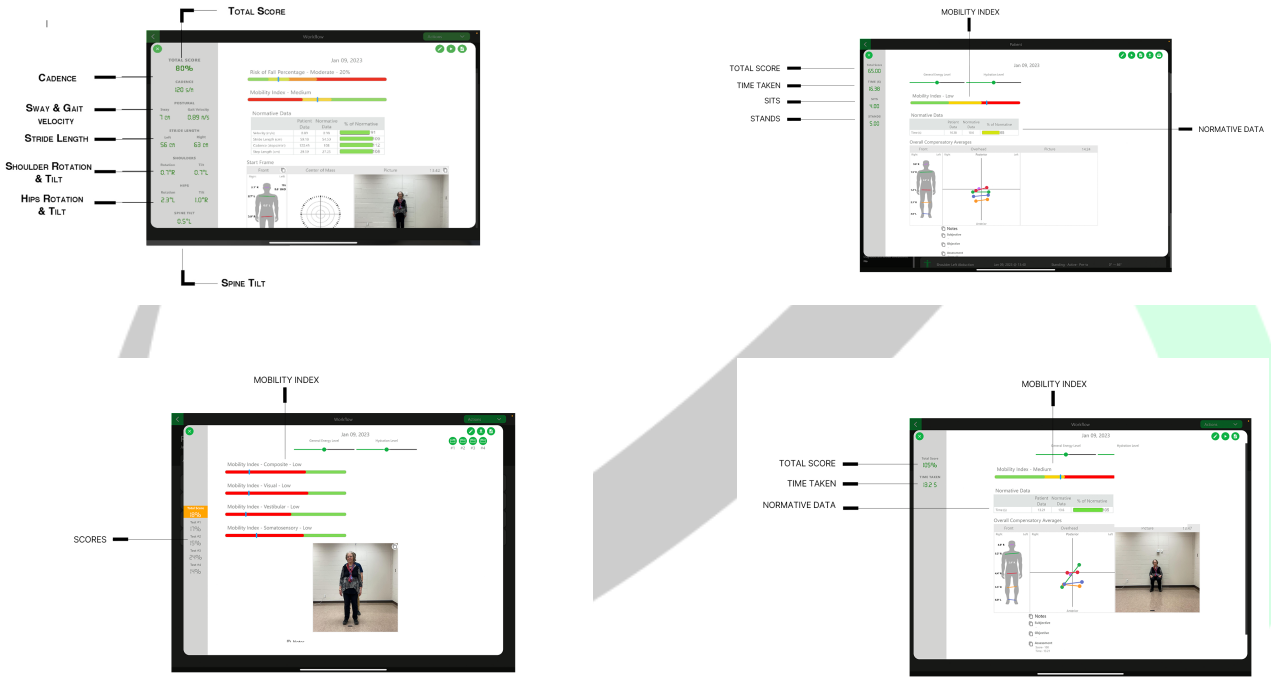


Fig. 4.

Figure 4 demonstrates the data outputs of the assessment. Each assessment contributes in part to the overall score.

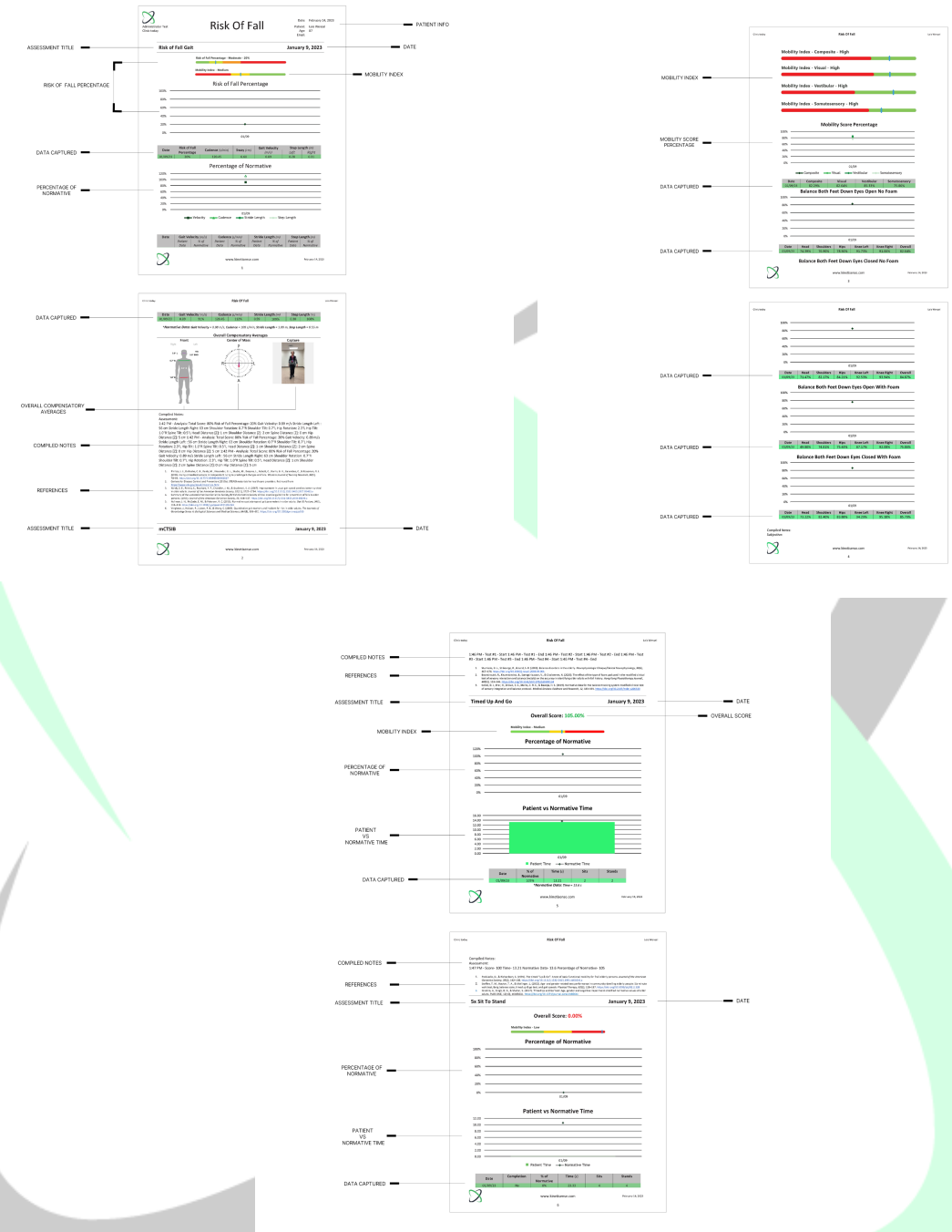


Fig. 5.

Figure 5 demonstrates the data outputs of the assessment. Each assessment contributes in part to the overall score.

The accuracy, ease of use and objectivity of the Kinetisense® system makes it an ideal tool for the clinical assessment of gait, the Kinetisense® system allows for a means of efficiently acquiring baseline gait analysis and reassessment. There are four modules in our Risk of Fall gait assessment.

The Risk of Fall Gait system will provide immediate data on the following:

1. Overall Risk of Fall Percentage Score.
2. Overall Functional Score.
3. Average Cadence.
4. Average Stride Length, left and right.
5. Gait Velocity.
6. Average Step Length.
7. Average Compensatory Shoulder Axis Tilt.
8. Average compensatory hip axis tilt (Trendelenburg).
9. Center of Mass Trace (CoM).
10. Trend data of overall gait improvements/regressions.

The Modified Clinical Test of Sensory Interaction and Balance (mCTSIB) provides four mobility scores as well as an overall score which is made up from the four balance segments.

1. The four mobility scores are: Composite, Visual, Vestibular and Somatosensory.

The Timed Up And Go (TUG) assessment provides immediate data on:

1. The Time Taken to Stand.
2. Recognition that the Patient Sat Back Down.
3. Overhead Planar Tracking.

The 5 Time Sit to Stand assessment provides immediate data on:

1. Automatic counting of a Patient's Sits and Stands.
2. Frontal Plane Tilt.
3. Overhead Planar Tracking.

This functional module analyzes a persons' Risk of Fall through an accurate and objective assessment.

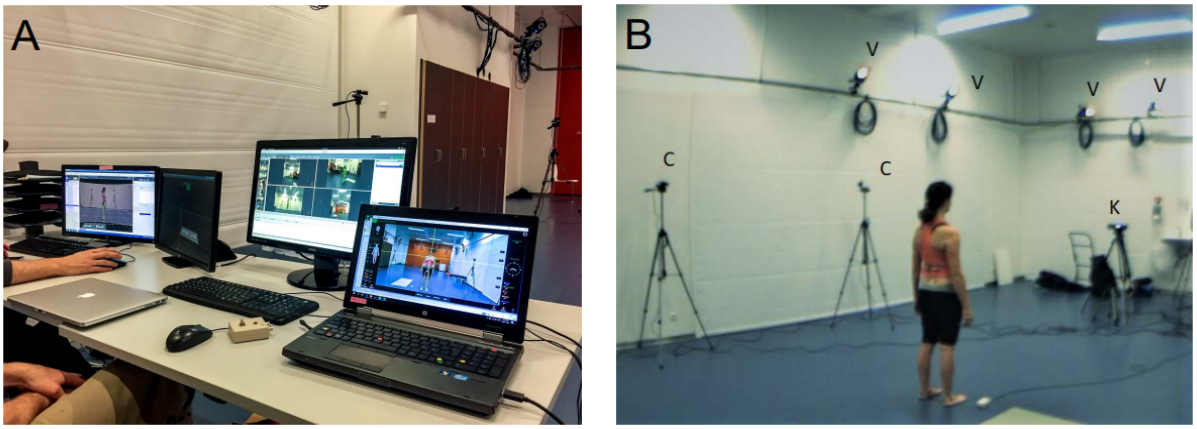
University Validation on the Accuracy of the Kinetisense System

The Kinetisense markerless motion system and associated SDK have been validated for accuracy as a biomechanical analysis tool in a variety of studies. It has shown reliability in measurement and inter-reliability in assessment and reassessment.

A study by Harsted et.al. entitled "The performance of two in-clinic markerless motion capture

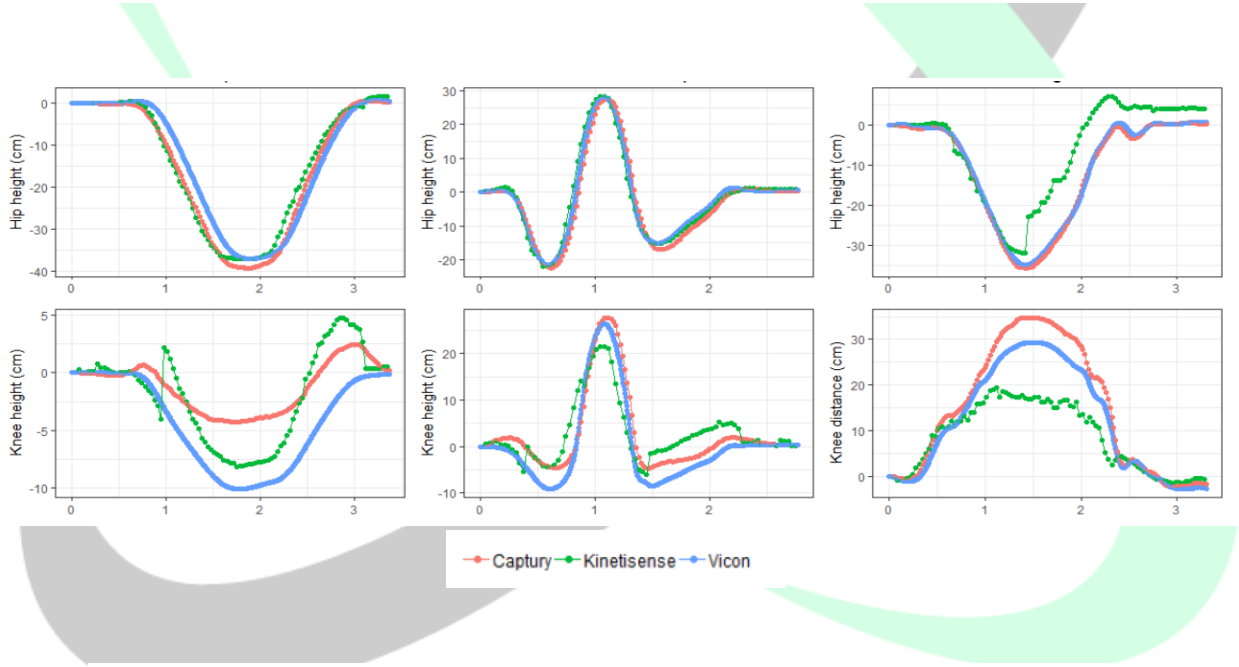
systems compared to a laboratory standard" found that Kinetisense showed good accuracy when compared to the Vicon marker-based system. This study concluded that the Kinetisense markerless system was "found to be sufficiently similar to the laboratory standard" of the Vicon system (20).

Biomechanical laboratory setup



A: From left to right Vicon (2 monitors), Captury, and Kinetisense

B: The subject standing in the center of the capturing volume of all three systems. Hardware from the three systems are marked with C (Captury), K (Kinetisense), and V (Vicon).



A third party University study conducted at the University of Calgary compared the accuracy of the Kinetisense system to the Vicon research system. The study compared the accuracy of the Kinetisense markerless system to the Vicon research system and force plate technology.

In conclusion the study suggests that "Kinetisense may be a valid alternative to expensive and cumbersome force plate or multi-camera motion analysis systems for clinical assessment. The objective scoring provided by the 3D tool improves upon current clinical standards that rely on scoring sheets or

subjective interpretation of 2D video. The ease of set-up and the quick turnaround of objective balance data allow the clinician to fully dedicate themselves to interacting with and assessing the patient. Instead of calibrating cameras, placing markers, and processing data the clinician can spend their time working with the patient to interpret the results, discuss their progress, and develop training plans".

A third party validation study conducted by Dr. Jon Doan from the University of Lethbridge compared the accuracy of the Kinetisense system to the Vicon research system. In this study 24 healthy young adults performed 8 different actions, each to two different levels (specific normal range deflection, maximal deflection) and at one of two different clinically relevant camera-subject distances, inside the shared calibration volume of the Kinetisense and VICON Peak motion capture systems. Bland-Altman agreement analysis was used to compare perceived and maximum joint angles from the Kinetisense system and the VICON Peak.

The results of this study showed that the "Kinetisense measures are valid compared to VICON-Peak measures, based on Bland-Altman agreement analysis".

Conclusion:

The Kinetisense® Risk of Fall assessment system provides an objective, efficient and affordable solution for risk assessment of falls in the elderly population. The high inter and intra-examiner reliability of the Kinetisense® system allows for reproducible joint and joint axis assessment in the frontal, sagittal and transverse planes. Kinetisense® provides the advantage of analyzing joints and joint axis in the assessment of gait, allowing for specific rehabilitation of the areas of the body where abnormal gait persists.

The Kinetisense® system allows health care providers to quickly identify risk factors associated with falls and initiate the proper balance and strength training program in a timely manner. This system will assess the individuals that are at greatest risk of falls, monitor changes over time with aging, and reduce overall costs to healthcare regarding geriatric falls and injury.

References:

1. Porta S, Martínez A, Millor N, Gómez M, Izquierdo M. Relevance of sex, age and gait kinematics when predicting fall-risk and mortality in older adults. J Biomech. 2020 May;105:109723.

2. Toots A, Rosendahl E, Lundin-Olsson L, Nordström P, Gustafson Y, Littbrand H. Usual Gait Speed Independently Predicts Mortality in Very Old People: A Population-Based Study. J Am Med Dir Assoc. 2013 Jul;14(7):529.e1-529.e6.

3. Falls [Internet]. [cited 2023 Feb 9]. Available from: https://www.who.int/news-room/fact-sheets/detail/falls

4. Burt CW, Fingerhut LA. Injury visits to hospital emergency departments: United States, 1992–95. Natl Cent Health Stat. 1998;13(131).

5. Grisso J, Kelsey J, Strong B, Ghiu G, Maislin G, O'Brian L, et al. Risk Factors for Falls as a Cause of Hip Injury in Women. N Engl J Med. 1991;324(19):1326–31.

6. Parkkari J, Kannus P, Palvanen M, Natri A, Vainio J, Aho H, et al. Majority of Hip Fractures Occur as a Result of a Fall and Impact on the Greater Trochanter of the Femur: A Prospective Controlled Hip Fracture Study with 206 Consecutive Patients. Calcif Tissue Int. 1999 Sep;65(3):183–7.

7. Haentjens P. Meta-analysis: Excess Mortality After Hip Fracture Among Older Women and Men. Ann Intern Med. 2010 Mar 16;152(6):380.

8. United Nations, Desa, Population Division, World Population Prospects 2019: Highlights.

9. Maki BE. Gait Changes in Older Adults: Predictors of Falls or Indicators of Fear? J Am Geriatr Soc. 1997 Mar;45(3):313–20.

10. Prince F, Corriveau H, Hébert R, Winter DA. Gait in the elderly. Gait Posture. 1997 Apr;5(2):128–35.

11. Verghese J, Holtzer R, Lipton RB, Wang C. Quantitative Gait Markers and Incident Fall Risk in Older Adults. J Gerontol A Biol Sci Med Sci. 2009 Aug 1;64A(8):896–901.

12. Kerrigan DC, Lee LW, Collins JJ, Riley PO, Lipsitz LA. Reduced hip extension during walking: Healthy elderly and fallers versus young adults. Arch Phys Med Rehabil. 2001 Jan;82(1):26–30.

13. Hamacher D, Singh NB, Van Dieën JH, Heller MO, Taylor WR. Kinematic measures for assessing gait stability in elderly individuals: a systematic review. J R Soc Interface. 2011 Dec 7;8(65):1682–98.

14. Kwon MS, Kwon YR, Park YS, Kim JW. Comparison of gait patterns in elderly fallers and non-fallers. Gómez C, Schwarzacher SP, Zhou H, editors. Technol Health Care. 2018 May 29;26:427–36.

15. Huijben B, van Schooten KS, van Dieën JH, Pijnappels M. The effect of walking speed on quality of gait in older adults. Gait Posture. 2018 Sep;65:112–6.

16. Espy DD, Yang F, Bhatt T, Pai YC. Independent influence of gait speed and step length on stability and fall risk. Gait Posture. 2010 Jul;32(3):378–82.

17. Luukinen H, Koski K, Laippala P, Kivelä SL. Predictors for recurrent falls among the home-dwelling elderly. Scand J Prim Health Care. 1995 Jan;13(4):294–9.

18. MacAulay RK, Allaire TD, Brouillette RM, Foil HC, Bruce-Keller AJ, Han H, et al. Longitudinal assessment of neuropsychological and temporal/spatial gait characteristics of elderly fallers: taking it all in stride. Front Aging Neurosci [Internet]. 2015 Mar 18 [cited 2023 Feb 9];7. Available from: http://www.frontiersin.org/Aging_Neuroscience/10.3389/fnagi.2015.00034/abstract

19. Thaler-Kall K, Peters A, Thorand B, Grill E, Autenrieth CS, Horsch A, et al. Description of spatio-temporal gait parameters in elderly people and their association with history of falls: results of the population-based cross-sectional KORA-Age study. BMC Geriatr. 2015 Dec;15(1):32.

20. Thomas KS, Russell DM, Van Lunen BL, Colberg SR, Morrison S. The impact of speed and time on gait dynamics. Hum Mov Sci. 2017 Aug;54:320–30.

21. Karinkanta S, Heinonen A, Sievänen H, Uusi-Rasi K, Kannus P. Factors Predicting Dynamic Balance and Quality of Life in Home-Dwelling Elderly Women. Gerontology. 2005;51(2):116–21.

22. Toebes MJP, Hoozemans MJM, Furrer R, Dekker J, van Dieën JH. Local dynamic stability and variability of gait are associated with fall history in elderly subjects. Gait Posture. 2012 Jul;36(3):527–31.

23. Karabin MJ, Sparto PJ, Rosano C, Redfern MS. Impact of strength and balance on Functional Gait Assessment performance in older adults. Gait Posture. 2022 Jan;91:306–11.

24. Scaglioni-Solano P, Aragón-Vargas LF. Gait characteristics and sensory abilities of older adults are modulated by gender. Gait Posture. 2015 Jun;42(1):54–9.

25. Zouita S, Zouhal H, Ferchichi H, Paillard T, Dziri C, Hackney AC, et al. Effects of Combined Balance and Strength Training on Measures of Balance and Muscle Strength in Older Women With a History of Falls. Front Physiol. 2020 Dec 23;11:619016.

26. Gschwind YJ, Kressig RW, Lacroix A, Muehlbauer T, Pfenninger B, Granacher U. A best practice fall prevention exercise program to improve balance, strength / power, and psychosocial health in older adults: study protocol for a randomized controlled trial. BMC Geriatr. 2013 Dec;13(1):105.

27. Buchner DM, Cress ME, de Lateur BJ, Esselman PC, Margherita AJ, Price R, et al. A comparison of the effects of three types of endurance training on balance and other fall risk factors in older adults. Aging Clin Exp Res. 1997 Feb;9(1–2):112–9.

28. Buchner DM, Cress ME, de Lateur BJ, Esselman PC, Margherita AJ, Price R, et al. The Effect of Strength and Endurance Training on Gait, Balance, Fall Risk, and Health Services Use in Community-Living Older Adults. J Gerontol A Biol Sci Med Sci. 1997 Jul 1;52A(4):M218–24.

29. Reider N, Gaul C. Fall risk screening in the elderly: A comparison of the minimal chair height standing ability test and 5-repetition sit-to-stand test. Arch Gerontol Geriatr. 2016 Jul;65:133–9.

30. Whitney SL, Wrisley DM, Marchetti GF, Gee MA, Redfern MS, Furman JM. Clinical Measurement of Sit-to-Stand Performance in People With Balance Disorders: Validity of Data for the Five-Times-Sit-to-Stand Test. Phys Ther. 2005 Oct 1;85(10):1034–45.

31. Resource Algorithm for Fall Risk Screening, Assessment, and Intervention [Internet]. Centers for Disease Control and Prevention; 2019. Available from: https://www.cdc.gov/steadi/pdf/STEADI-Algorithm-508.pdf