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Comparing Usability and Variance of Low- and High Technology Approaches to Gait Analysis in Health Adults

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COMPARING USABILITY AND VARIANCE OF LOW- AND HIGH TECHNOLOGY APPROACHES TO GAIT ANALYSIS IN HEALTHY ADULTS

By

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A doctoral project submitted in partial fulfillment

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ABSTRACT

Purpose: The purpose of this study was to compare the usability, reliability, and objectivity of four tools that represented varying gait analysis technologies used in clinical practice and/or research. Low technology clinical tools included the Gait Abnormality Rating Scale (GARS-M) and the Rancho Los Amigos Observational Gait Analysis (Rancho OGA). High technology tools included the GAITRite® computerized walkway, and the APDM Mobility Lab™ wearable sensor system.

Subjects: 74 healthy adults ages 18-41 years (mean = 24.82, SD = 4.39) 33 males and 40 females.

Methods: Subjects were instructed to walk at a self-selected speed for two minutes during which clinical and spatiotemporal gait characteristics were measured concurrently using the four tools.

Results: A qualitative analysis was created to display usability characteristics for each tool. GARS-M and Rancho OGA yielded fair to moderate Inter-rater reliability scores (K=0.41, K=0.31) and moderate Intra-rater reliability scores ($ICC_{3,2}$=0.65, $ICC_{3,2}$ = 0.64, $ICC_{3,2}$=0.48, $ICC_{3,2}$=0.53). Comparison analysis of GARS-M and Rancho OGA resulted in a high specificity (Sp=0.96) and high positive likelihood ratio(+LR=13.6). No significant difference was found between the seven gait variables measured by GAITRite® and Mobility Lab™ however Pearson correlation analysis showed significant correlations between three of seven measured gait variables: cadence(p<0.001), gait cycle time(p=<0.001), and double limb support % of cycle(p=0.026).

Conclusion: This study showed the GARS-M and Rancho OGA may be useful for clinical gait analysis but objective data are not comparable to the high technology tools. The GAITRite® offers desirable objective data for research but usability factors and high cost may deter its use in the clinic. Mobility Lab™ may be the most suitable for both clinical and research use as it offers objective data

combined with established clinical measures and more favorable usability factors compared to GAITRite®.

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INTRODUCTION

The loss of walking is a common and costly problem that can have a devastating impact on the way individuals participate in the world around them and engage in whole body activities in differing environments. Further, loss of the ability to walk can influence health, wellness, morbidity and mortality. For this reason, walking is classified as a major life activity under the Americans with Disabilities Act.[1] In the United States alone, 30.6 million people over the age of 15 experience difficulty with ambulation activities involving the lower extremities and 7.0 million people aged 65 and over use an assistive device such as a cane, crutches or walker to aid in their ambulation.[2] Over 17 million adults in the United States ages 18 and over, have significant difficulty or are completely unable to walk at least one quarter mile.[3] In addition, an approximate 580,000 children ages 6-14 in the U.S. have difficulty walking or running.[2] It is estimated that each year $300 million is spent on healthcare to treat physical disabilities that involve walking through direct and indirect costs.[4]

In addition to financial and productivity costs, losing the ability to walk may also lead to a lifestyle of inactivity and therefore have a negative impact on one's health by affecting multiple body structures and functions which may include bone health, cardiovascular health, and even psychological health.[5, 6] A recent study done by Lee et al,[7] reported that physical inactivity causes an estimated six to 10% of non-communicable diseases worldwide including coronary artery disease, type II diabetes, breast cancer and colon cancer and also contributes to 9% of premature mortality. Additionally, loss of walking diminishes protective effects of physical exercise seen in the general population and a variety of patient populations including individuals with stroke and Parkinson's disease. One basic tenet of patient-centered care is that rehabilitation goals should be mutually agreed upon by providers and patients, and patients very frequently identify a return to walking or improvement of walking as a high priority when asked about their goals for physical therapy episodes of care. For physical therapists and others rehabilitation providers, understanding the cause of the problem is critical to being able to successfully address it and achieve the desired outcomes.

A myriad of tools that focus on or include gait analysis are available across every level of the International Classification of Functioning, Disability, and Health (ICF).[8] At the level of participation, tools such as the Six-minute walk and the 10 meter walk test focus on whether an individual has adequate walking skills to take part in a variety of roles at home and in the community.[9] At the level of activity, tools such as the Dynamic Gait Index and the Functional Gait Assessment examine how well a person is able to walk at the level of the whole individual's function. At the level of body structure and function, tools such as strength or range of motion testing analyze specific factors that may contribute to gait deviations or issues with functional mobility. Clinical gait analysis tools, such as the Rancho Los Amigos Observational Gait Assessment[10] (Rancho OGA) and the Modified Gait Abnormality Rating Scale[11] (GARS-M) are widely used and reflect only two of the many different tools used in clinical gait analysis. In fact, the *Guide to Physical Therapist Practice*[12] identifies 20 different observational tests and measures for the purpose of analyzing gait, all of which can be obtained for minimal to no cost. The rise of evidence-based practice, increased accountability of rehabilitation professionals to effectively address gait outcomes of their patients, and the dramatic increase in the quality and quantity of rehabilitation research have contributed to technological advancements in gait analysis tools designed to improve precision and repeatability of measurements of varying aspects of gait.

Quantitative data collected from motion analysis equipment can offer a wealth of information about human kinematics, kinetics, joint movements, and spatio-temporal gait variables such as cadence, average stride length, and walking speed. However, the time, space, expense, and training involved in the use of fixed motion capture systems presently put them out of reach for practical clinical use, creating a gap between quantifiable data analysis gathered for research purposes in the laboratory and the tools presently used in clinical practice.

Advancements in portable technologies may create a bridge that is practical for clinical gait analysis outside of the controlled laboratory, and precise enough for use in research. Gregory et al,[13] demonstrated the use of portable accelerometers as a means to measure movement or accelerations of body segments during movement with the capability of approximating the body's center of mass with less than 5% error. Other wearable technologies including those that incorporate accelerometers with gyroscopes such as the Mobility Lab system™ are considered to be a viable and lower cost alternative to fixed motion capture with potential for precision[14] that may exceed some observational methods.

Other devices use computerized pressure detection methods to examine patterns of pressures exerted by each foot as it contacts the support surface and moves through the gait cycle. Pressure-sensitive insoles that can be worn inside the individual's shoes are one method of applying this technology[15], while computerized mats such as the GAITRite® mat and Protokinetics walkways incorporate pressure detection as the individual moves over a path of pressure sensors.

With the vast number and types of tools available, clinicians and researchers must review and weigh the psychometric properties of the possible tools they are considering for use in gait analysis, and the purposes for which they are examining an individual's gait whether or not they incorporate technology into the analysis. When researchers and clinicians do not use the same measurement tools, the ability of clinicians to apply research-based evidence in their clinical practice is dampened, slowing the process of translating scientific discoveries into clinical reality.[16]

The purpose of this study was to compare and contrast a selection of commonly used observational gait analysis tools with two types of portable gait assessment technologies in an effort to aid clinicians and researchers in their decision making processes. The specific aims of the study were: (1) to complete a qualitative analysis of usability factors of each of the four tools; (2) to examine intra-rater and inter-rater reliability of the observational tools; (3) to examine variability between the portable technology tools; and (4) to examine the ability of each of the observational tools compared to each other and to the computerized walkway to detect gait deviations where they existed in our sample.

METHODS

Design

For the purpose of this study we used a cross sectional study design in order to compare and contrast data obtained from multiple systems in the same individuals at a single point in time. Video recordings of these same trials were collected for replay in order to test and support reliability and adherence to the protocol. The study was approved by and conducted under supervision of the Institutional Review Board of the University of Nevada Las Vegas[1].

Subjects

A sample of convenience (n=74) was recruited by email, flyer, and word of mouth on the campus of the University of Nevada, Las Vegas. The sample included healthy adults aged 18 to 41 years (mean = 24.82, SD = 4.39) who were able to ambulate at least 50 feet independently; and had no known neuromuscular condition or active orthopedic injury to the lower extremity. Enrollees who did not meet inclusion criteria or were past the second trimester of pregnancy were excluded from participation. Participants for whom the Ambulatory Parkinson's Disease Monitoring (APDM) Mobility Lab™ [17] system failed to collect data (n=5) were excluded from the analyses involving Mobility Lab™.

[1] BM 1311-4638

Instrumentation

The tools used in the study were chosen because they represented a range of tools and technologies currently used in clinical practice or research of which gait analysis is a part. The GARS-M and Rancho OGA are commonly used in clinical practice and do not require equipment beyond a scoring sheet. The GAITRite® and APDM Mobility Lab™ represented gait analysis tools that utilize different types of technology to collect information on spatiotemporal gait characteristics across a variety of healthy and patient populations.

GAIT ABNORMALITY RATING SCALE – Modified (GARS-M)

The GARS-M[(Appendix C)] is an observational gait analysis tool that is often used in a clinical setting to quickly identify atypical patterns of gait. The GARS-M does not require any equipment other than a copy of the scoring sheet and a writing implement, thus was considered a low technology tool for purposes of this study.

The GARS-M has long been used in clinical settings and has been shown to have a sensitivity of 62.3% and a specificity of 87.1%[18,19] for identifying gait deviations. This tool scores seven components of gait on an ordinal four-point scale (0-3), with a higher score representing greater gait abnormality. Subjects were observed by two researchers (BS and JM) in both the frontal and sagittal planes while walking at a self-selected gait velocity and were scored on each of the seven items by both researchers.

RANCHO LOS AMIGOS Observational Gait Analysis (Rancho OGA)

The Rancho OGA(Appendix D) is one of the most commonly cited observational assessment tools in literature and was developed by the staff at Rancho Los Amigos Hospital in California in order to quickly identify gait abnormalities without the use of an instrumented gait assessment tool.[20] Observations are recorded on a form with boxes for the examiner to place a tick mark if an abnormality is identified. The examiner looks at movement in the trunk, pelvis, hip, knee and ankle/foot during different segments of the stance and swing phases of gait and marks the form where they identify an abnormality. The RanchoGait app© is also available for use on a phone or tablet which is free to download but has various in-app purchases available depending on the functionality and usability that the examiner desires. The app was not used in this study, but rather a pen and paper method was used instead.

APDM Mobility Lab™

The Mobility Lab™ is an example of a recently developed moderate to high technology motion analysis system. This motion capture system uses six wireless sensors attached with Velcro straps to various parts of the participants' body in order to provide a three dimensional evaluation of movement in space. The body locations to which the sensors were attached the left and right wrists, left and right legs, chest and waist; the standard application as directed in the APDM user manual (Figure 1). The chest sensor was placed over the sternum of each participant just below the manubrium. The waist sensor was placed on the lower back between the two posterior superior iliac spines. Each sensor contains an accelerometer, a gyroscope and a magnetometer to determine orientation and movement of the sensor and the body part to which it is attached. The sensors upload the collected information from each trial to the Mobility Lab™ software where the data can then be interpreted. The Two-Minute Walk protocol and settings were selected in the Mobility Lab™ software during the collection of data in this study.

GAITRite®

GAITRite® is an example of high technology, two-dimensional gait analysis used in research and in other settings.[21,22,23] The GAITRite® mat used for this study measures 12 feet in length and contains pressure sensors to detect foot placement and pressure during ambulation (Figure 2). The mat was laid within a 20-foot walkway to allow turning space on either end of the mat. Subjects were instructed to walk across the mat with each pass.

Procedure

Subjects were recruited from the University of Nevada, Las Vegas (UNLV) through word of mouth. All subjects gave their informed consent and had their questions answered prior to data collection. All subjects were then screened for eligibility and demographic and related information was collected on a brief questionnaire. All data were collected in the in the Paul McDermott Physical

Education Complex (MPE) on the campus of UNLV for screening and data collection sessions.

Testing was performed by two Doctor of Physical Therapy (DPT) students and one biomechanics masters student trained in operating the GAITRite®. Subjects were instructed to walk at a comfortable self-selected pace for two continuous minutes back and forth across the GAITRite® mat without stopping while wearing the Mobilty Lab™ sensors. Subjects walked across a flat 20-foot pathway. When the subject reached the end of the designated pathway they turned around and returned along the same path. This was continued for the full two minutes of gait evaluation during which time gait was simultaneously analyzed with all four gait analysis tools and subjects were filmed from the frontal and sagittal plane with two standard video cameras. Data were collected concurrently with each high-tech gait analysis tool for the full two-minutes. Subjects were filmed by two video cameras from frontal and sagittal planes. A large running timer was utilized throughout the gait analysis testing for video recording accuracy when viewing trials at a later time. GARS-M and Rancho OGA were performed by the two DPT students simultaneously for each subject during the two-minute walking trial. Both DPT students received exposure and training on implementing the GARS-M and Rancho OGA through the UNLV DPT program.

Analysis

Usability was analyzed using a qualitative analysis across the 4 tools. Intra-rater reliability was assessed using the Kappa statistic for each of the examiners for each clinical tool (GARS-M and Rancho OGA). Inter-rater reliability of the clinical tools was assessed using the Intraclass Correlation Coefficient Model 2 (ICC_2). The strength of association between the two clinical tools by each examiner was evaluated using the Spearman's rank correlation statistic. The Chi-square statistic was examined for each clinical tool to evaluate the level of agreement between the data collected. Diagnostic accuracy for comparing the ability of the two clinical tools to identify gait deviations was tested using a 2x2 contingency table to examine: sensitivity, specificity, +/- likelihood ratio, +/- predictive value, number needed to treat, and diagnostic odds.

Relationships between values for specific gait parameters: stride length(m), cadence(steps/min), cycle time(sec), stride velocity(m/s), double support%, swing% of cycle, and stance% of cycle as measured using GAITRite® and Mobility Lab™ were examined as follows. Variability between the specific gait parameters was evaluated using paired sample t-test analyses. The agreement between the specific gait parameters was evaluated using the Pearson Correlation Coefficient statistic (PCC). All were set to $\alpha=0.05$. All quantitative analyses were carried out using IBM SPSS Statistics 20.0 (IFM In, Armonk, New York).

Results

Qualitative analyses of the four gait tools showed no set up time required for both GARS-M and Rancho OGA with an approximate 10 min set up time for both the GAITRite® and Mobility Lab™. Equipment required for both GARS-M and Rancho OGA includes a writing utensil and a physical copy of their respective form. Currently there is an option for a mobile device app for Rancho OGA. Both the GAITRite® and Mobility Lab™ require specific equipment and the use of a computer to run their respective software. There is no training required to use the GARS-M however a clinically trained eye will be usefully in determining the presence of deviations listed within the GARS-M. Training required to use the Rancho OGA at a minimum requires an expert understanding of the Rancho Los Amigos phases of gait. Both the GAITRite® and Mobility Lab™ include tutorials to assist the user in orienting themselves with software and equipment. Space requirements for both GARS-M, Rancho OGA, and Mobility Lab™ only require the minimum desired walking distance set by the examiner. GAITRite® space requirements are constricted to the length of the mat. See Table 2 for side by side comparison between all 4 tools.

Tests for inter-rater reliability revealed a moderate Kappa score between Rater 1 and Rater 2 for GARS-M(K=0.41) and a fair Kappa score between Rater 1 and Rater 2 for Rancho OGA(K=0.31).[24]

Tests for intra-rater reliability revealed a moderate degree of correlation between Rater 1 live vs video rescore of GARS-M($ICC_{3,2}$=0.65) and Rancho

OGA($ICC_{3,2}$ = 0.64) and a moderate degree of correlation between Rater 2 live vs video rescore of GARS-M ($ICC_{3,2}$=0.48) and Rancho OGA($ICC_{3,2}$=0.53).[25]

Spearman's rank nonparametric correlation analysis tests revealed similar numbers to both the Kappa statistic tests and $ICC_{3,2}$ tests. Rater 1 vs Rater 2 for GARS-M(r_s=0.41) and for Rancho OGA(r_s=0.31). Rater 1 live vs video rescore for GARS-M(r_s=0.65) for Rancho OGA(r_s=0.65). Rater 2 live vs video rescore for GARS-M(r_s=0.49) for Ranco OGA(r_s=0.56).

Chi-square analysis for all inter-rater and intra-rater reliability tests revealed significant differences for all values. Rater 1 vs Rater 2 for GARS-M(p <.001) for Rancho OGA(p=.008). Rater 1 live vs video rescore for GARS-M(p <.001) for Rancho OGA(p<.001). Rater 2 live vs video rescore for GARS-M(p <.001) for Rancho OGA(p<.001).

The 2X2 contingency table comparison analysis between GARS-M and Rancho OGA revealed a low sensitivity(Sn=0.20), high specificity(Sp=0.96), a high positive likelihood ratio(+LR=13.6), a low likelihood ratio(-LR=1.03), positive predictive value(+Pv=0.50), negative predictive value(-Pv=0.94), diagnostic odds(DO=16.75, and number needed to diagnose(NND=2.25). See Table 4 for set up and details.

Comparisons between GAITRite® and Mobility Lab™ were examined by through the implementation of paired sample t-test analyses. These results revealed no significant differences between GAITRite® and Mobility Lab™ in terms of stride length (p=0.189), cadence(p=0.357), cycle time(p=0.338), stride velocity(p=0.214), double support percentage of cycle (p=0.375), swing percentage of cycle ($p=0.126$), and stance percentage of cycle ($p=0.161$) Results from paired sample t-test analyses including the mean, standard deviation, standard error of the mean, and p values for both GAITRite® and Mobility Lab™ are depicted in Table 5.

Pearson correlation analysis was performed to examine the degree of agreement between both high-technology tools for each variable. The Pearson correlation coefficients showed that there were significant associations in cadence ($r= 0.685$, $p < 0.001$; Figure 4), gait cycle time($r= .678$, $p < 0.001$; Figure 5), and double limb support time ($r=0.270$, $p =0.026$; Figure 7) between Mobility Lab™ and GAITRite®. There were not significant associations between the 2 methods in stride length($r=0.187$; $p=0.128$; Figure 3), stride velocity($r=0.164$, $p=0.180$; Figure 6), stance percent of cycle ($r =0 .035$, $p=0.778$; Figure 8), and swing percent of cycle ($r=0 .186$, $p= 0.128$; Figure 9).

DISCUSSION

With high rates of gait disturbances affecting a significant number of people the need for affective treatment and prevention is important. With such a wide variety of gait analysis methods available, it is important to choose the method best suited for the researcher's or clinician's needs based on the patient, research purpose, budget, time, and available space.

Each gait analysis tool used in this study presents both advantages and disadvantages with its use. Factors such as reliability, usability, cost, required training, set up time, required equipment and required space are factors that are commonly considered when choosing the analysis tool most appropriate for a given setting and specific patient population.

Due to the observational nature of the GARS-M and the Rancho OGA, the data gathered were far less sensitive to joint angles and other quantitative deviations within the gait cycle and therefore these tools were not as sensitive for picking up minor gait deviations in a population of healthy young adults with no reported major gait deficits. However, the measured high specificity of 0.96 and positive likelihood ratio of 13.6 suggest these tools may be useful in ruling in the presence of a major gait deviation. Qualitative analyses of the GARS-M and the Rancho OGA depict both tools as being relatively inexpensive and require little time to administer which may be paramount in choosing to use such tools within the clinical realm. Fair to moderate inter-rater reliability scores and moderate intra-rater reliability scores suggests a degree of subjectivity exists between testers as well as variation in scores on the same subject between live and video rescores.

Results from the repeated measures paired t-tests for high technology gait analysis tools showed no significant difference in any of the seven investigated gait variables. This indicates that the measurements of gait are similar between the GAITRite® and Mobility Lab™. However, Pearson correlation analysis showed a significant correlation between only three of the seven measured gait variables. These discrepancies suggest the two portable high technology gait analysis tools may not be reliable for interchangeable scoring on the same patient. These high technology analysis tools allow for the collection of detailed objective data that may be beneficial to a clinician or researcher and may not be available when using low technology observational analyses.

This study offered a unique chance to evaluate four gait analysis tools from a vast variety of gait analysis methods. It is important to reiterate the absence of a gold standard technique for gait analysis leaves the clinician and researcher with important decisions to make with regards to choosing their analysis method. To better aid clinicians and researchers, information on the psychometric properties of tools can be found in such resources as the Guide to Physical Therapist Practice, the National Institutes of Health toolbox, Strokengine, and the Neurology Section of the American Physical Therapy Associations Outcome Measures Recommendations resources.

Further research examining high technology and low technology based gait assessments on populations with specific musculoskeletal or neurological gait impairments will be beneficial to further comment on the accuracy, sensitivity, and usability of these tools in specific settings. Continued studies examining response of patient populations to specific rehabilitation interventions with a strong evidence base using similar sampling of tools used in gait analysis including portable technologies that yield data useful in the clinic and for research will be important to further investigate whether these tools are sensitive to change when actual change has occurred.

LIMITATIONS

This study had limitations that must be considered when interpreting or applying findings. The sample of subjects that participated in this study had a narrow age range (mean age 24.5, range 18 to 41) which does not accurately represent the general population as a whole. Another limitation is this sample of participants included physically healthy individuals and excluded any participants with acute orthopedic or known neurologic injuries affecting their ability to walk distances of 100 feet or greater. This therefore minimized gait variations and made the subjects' gait difficult to assess using the less sensitive observational tools.

The low technology observational gait tools were implemented by DPT students with a basic foundation in gait assessment. The addition of examiners with more clinical experience in gait assessment will be beneficial for future research on the reliability of observational gait analysis tools.

We acknowledge that technology is an ever-growing and constantly developing field which is constantly yielding new instruments for gait analysis. We were not able to include every gait analysis tool and chose to use two high technology tools that were available at the time of our study.

CONCLUSION

This study found the GARS-M to be a quick and easy tool to use that requires little instruction and may be feasible as an outcome measure for persons with significant gait impairments. The GARS-M does not provide sensitive measurements and is not recommended for analyzing minor gait disturbances. The Rancho OGA offers a much more in depth gait analysis that will require more time and relies heavily on the administrator's ability to detect variations within the eight phases of gait. With the addition of video cameras and inter/intra reliability measures the Rancho OGA may be a feasible qualitative measure in the research laboratory. The GAITRite® is the closest to a gold standard method of gait analysis used due to its establishment in multiple research studies and lack of a true gold standard quantitative gait analysis method. However of the tools examined in this study the GAITRite® is the most expensive, has the longest set up time, requires the most space, and requires the most technical training to administer making this method better suited for a research setting. The Mobility Lab™ may be the most suitable for both clinical and research use as it offers objective data combined with established clinical measures and more favorable usability factors as compared to GAITRite®, such as less required space and less required technical understanding of the software in order to be used effectively.

APPENDIX A – Tables

Table 1. Participant Demographics

Participant Demographics			
	N (% of total)	Height(cm) Mean	Weight(Kg) Mean
Total	73 (100%)	170.36	68.9
Gender Male Female	 33 (45%) 40 (54%)	 177.5 164.3	 77 62
Age Mean = 24.82 SD = 4.39 (18-24) (25-34) (>34)	 41 (55%) 28 (38%) 5 (7%)	 167.7 173.2 176.4	 66.6 71.3 74.1
Had a fall in the last year? Yes No	 5 (7%) 69 (93%)		

Table 2. Qualitative Comparisons Across 4 Gait Tools

Qualitative Comparisons Across Gait Tools				
	GARS-M	Rancho OGA	Mobility Lab™	GAITRite®
Set up time Required	No set up time	No set up time	Approximately 10 minutes	Approximately 10 minutes
Equipment Required	Writing utensil, GARS-M form, Optional video	Writing utensil, Ranch OGA form, Optional video	Computer with Mobility Lab™ software, Mobility Lab™ sensors	Computer with GAITRite software, GAITRite mat
Training Required	None required	Understanding of gait cycle	Software tutorial	Software tutorial (Approximately 2 hours)
Space Required	Minimum desired walking distance	Minimum desired walking distance	Minimum desired walking distance	Approximately 20 feet of straight and level walking space
Subject must be prepped or fitted with equipment?	No	No	Yes	Yes

Table 3. Intra-rater and Inter-rater Reliability

Reliability of Low Technology Clinical Observation Tools					
	% agreement	Kappa	Spearman's r	ICC	Chi-square (p)
Intra-rater					
Rater 1 (JM) GARS-M live vs video rescore	96%	0.650	0.650	0.648	0.000
Rater 2 (BS) GARS-M live vs video rescore	95%	0.473	0.490	0.476	0.000
Rater 1 (JM) Rancho live vs video rescore	90%	0.648	0.648	0.643	0.000
Rater 2 (BS) Rancho live vs video rescore	88%	0.540	0.558	0.543	0.000
Inter-rater					
Rater 1 (JM) vs Rater 2 (BS) GARS-M	93%	0.408	0.411	0.412	0.000
Rater 1 (JM) vs Rater 2 (BS) Rancho	81%	0.306	0.307	0.309	0.008

Table 4. GARS-M and Rancho OGA Contingency Table

Diagnostic Accuracy of GARS-M compared to Rancho OGA as Gold Standard				
	Rancho OGA Cases			
	Cases n (%)	Controls n (%)		
GARS-M Cases n (%)	1	1	+ Predictive Value = 0.500	Number Needed to Diagnose = 2.254
GARS-M Controls n (%)	4	67	- Predictive Value = 0.944	
	Sensitivity =0.200	Specificity =0.985		
	+ Likelihood Ratio = 13.600	- Likelihood Ratio = 1.030	Diagnostic odds = 16.750	

Table 5. Results from GAITRite® and Mobility lab™

Differences in spatiotemporal gait characteristics measured by Mobility Lab™ and GAITRite® during analysis at a self-selected walking speed(SSWS)							
Variable	Mobility Lab™ (mean)	Mobility Lab™ Std. deviation	Mobility Lab™ (SEM)	GAITRite (mean)	GAITRite Std. deviation	GAIT Rite (SEM)	Paired t test significance P value
Stride length(m)	1.653	1.815	.220	1.364	.153	.019	.189
Cadence (steps/min)	108.524	6.981	.847	109.150	7.025	.852	.357
Cycle Time (sec)	1.111	.0735	.009	1.104	.072	.009	.338
Stride Velocity (m/s)	1.493	1.614	.196	1.250	.141	.017	.214
Double Support %	24.748	6.356	.771	25.416	2.480	.301	.375
Swing % cycle	38.109	4.684	.568	37.241	1.256	.152	.126
Stance % cycle	61.980	4.417	.536	62.76	1.256	.152	.161

APPENDIX B – Figures

Figure 1. APDM Mobility Lab™ and GAITRite® Systems

Arrows indicate sensor placement, GAITRite® mat outlined.

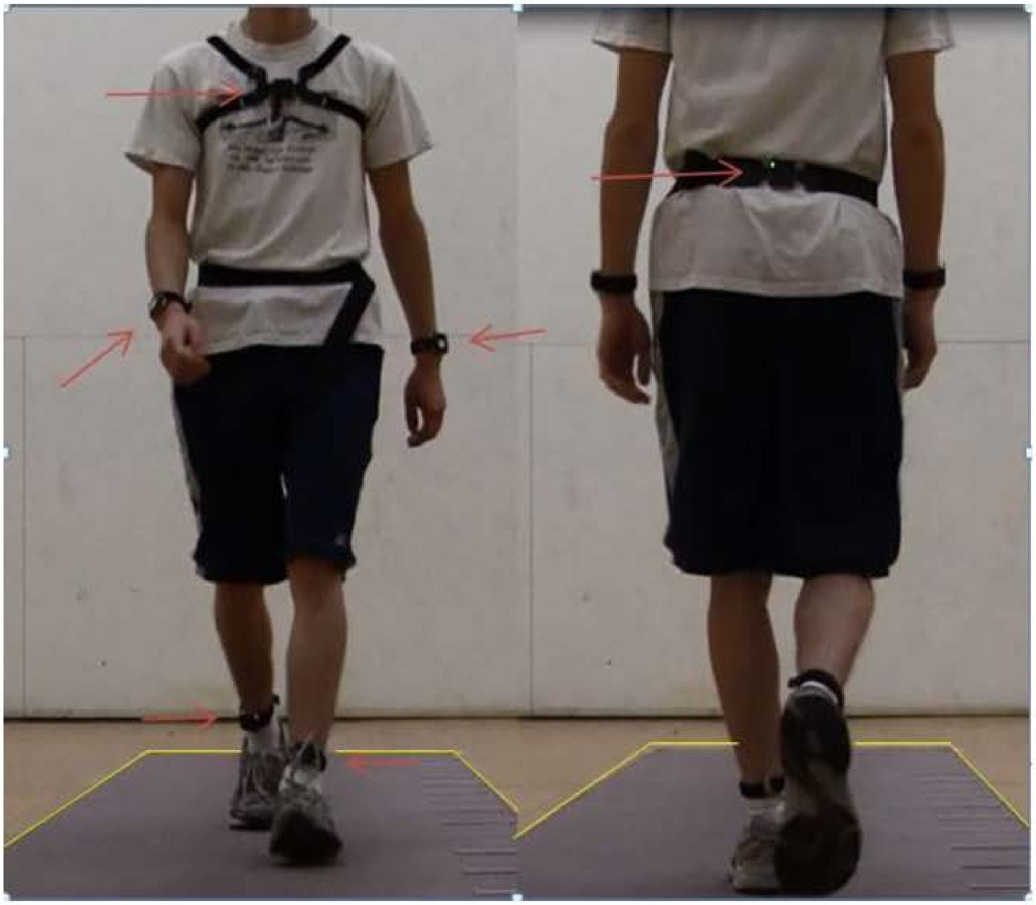


Figure 2. Research Flow Chart

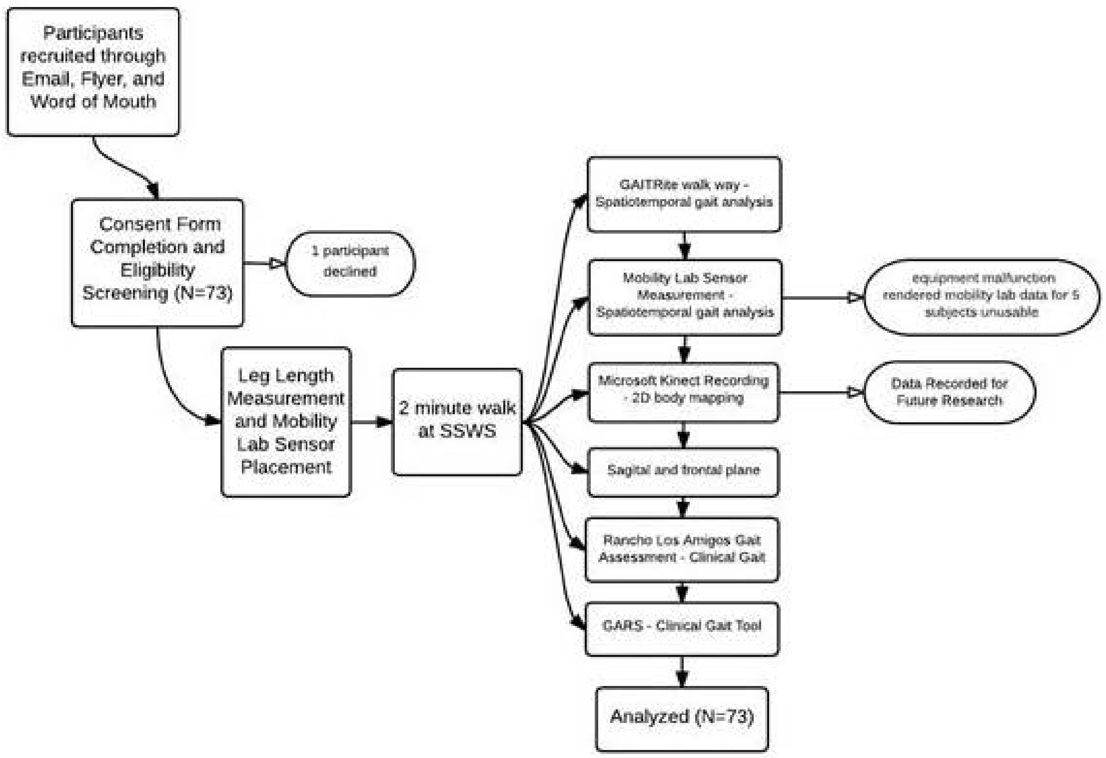


Figure 3. The Pearson Correlation Coefficient of stride length between MobilityLab™ and GAITRite® ($r = 0.187$; $p = 0.128$).

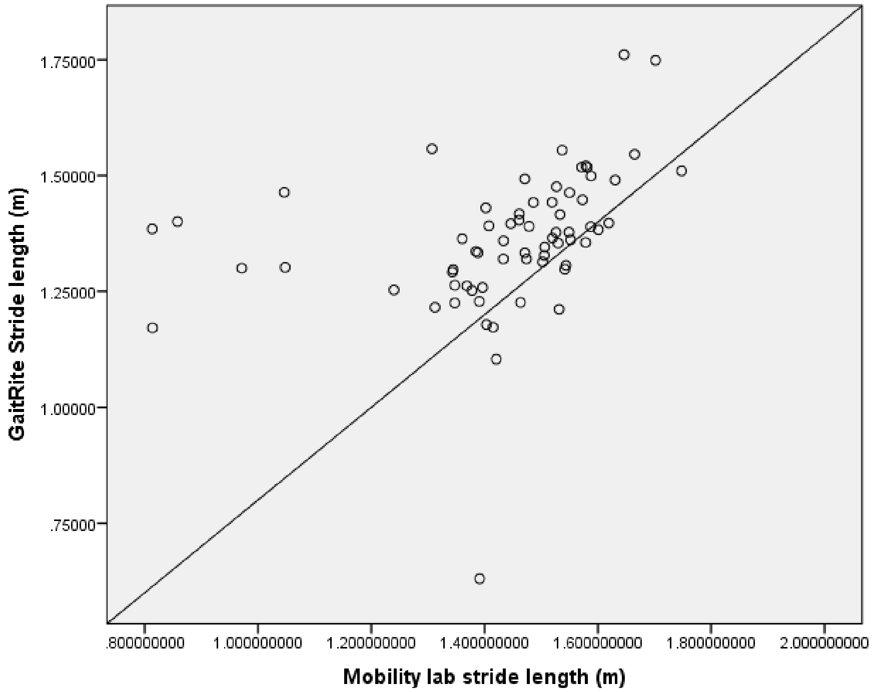


Figure 4. The Pearson Correlation Coefficient of cadence between MobilityLab™ and GAITRite® ($r = 0.685$; $p < 0.001$).

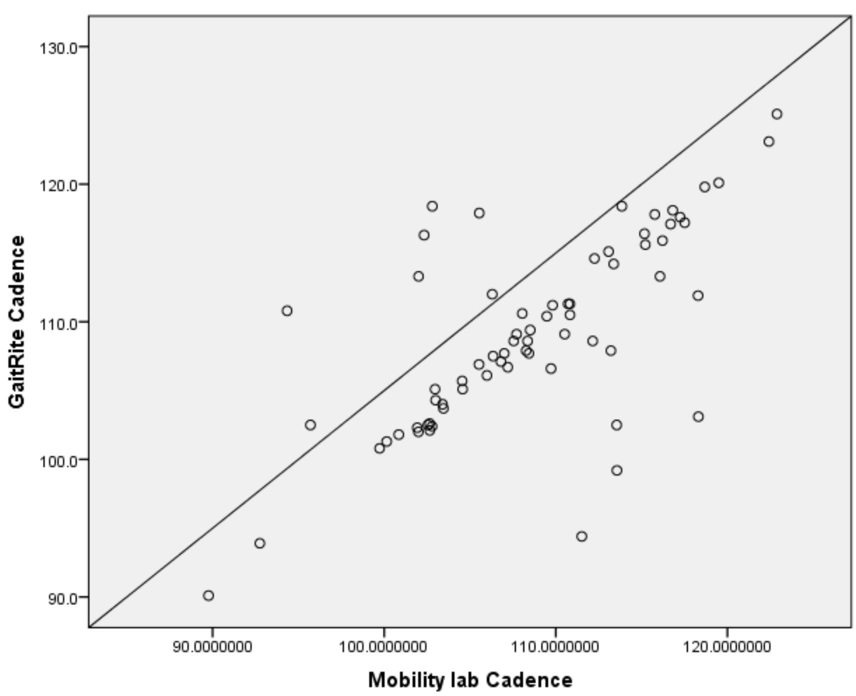


Figure 5. The Pearson Correlation Coefficient of cycle time between MobilityLab™ and GAITRite® (r = 0.678; p < 0.001).

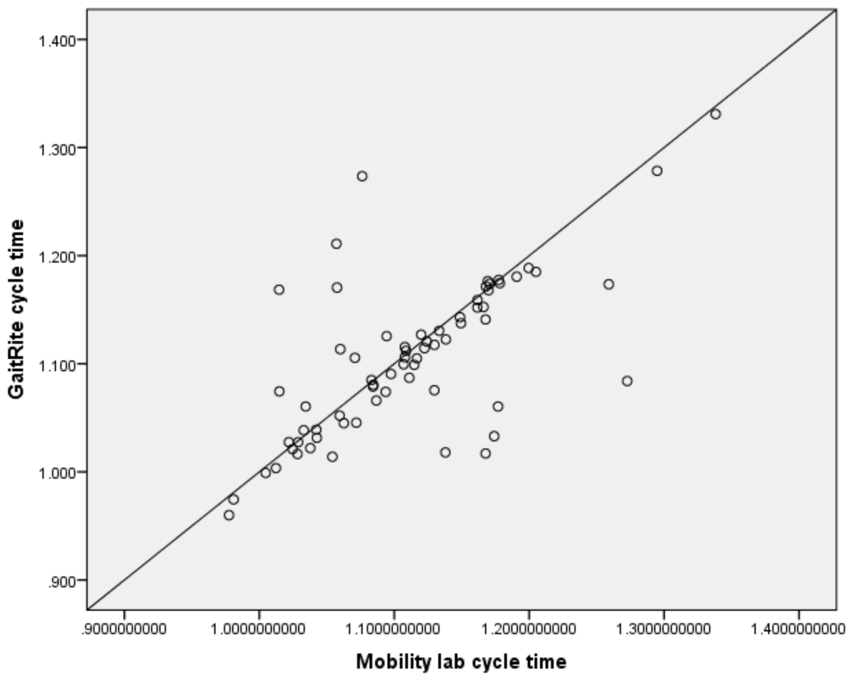


Figure 6. The Pearson Correlation Coefficient of stride velocity between MobilityLab™ and GAITRite® (r = 0.164; p = 0.180).

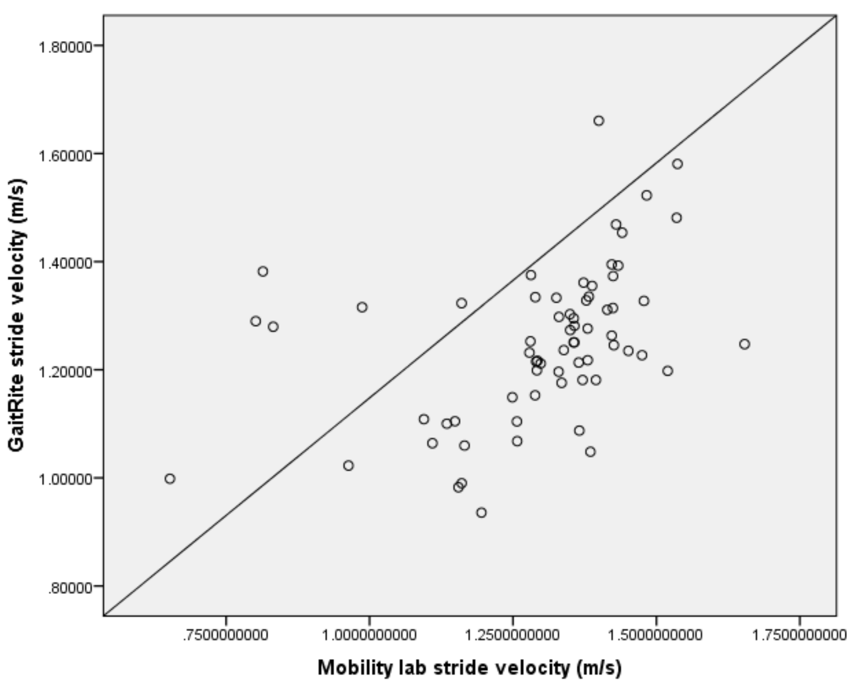


Figure 7. The Pearson Correlation Coefficient of double support % between MobilityLab™ and GAITRite® (r = 0.270; p = 0.026).

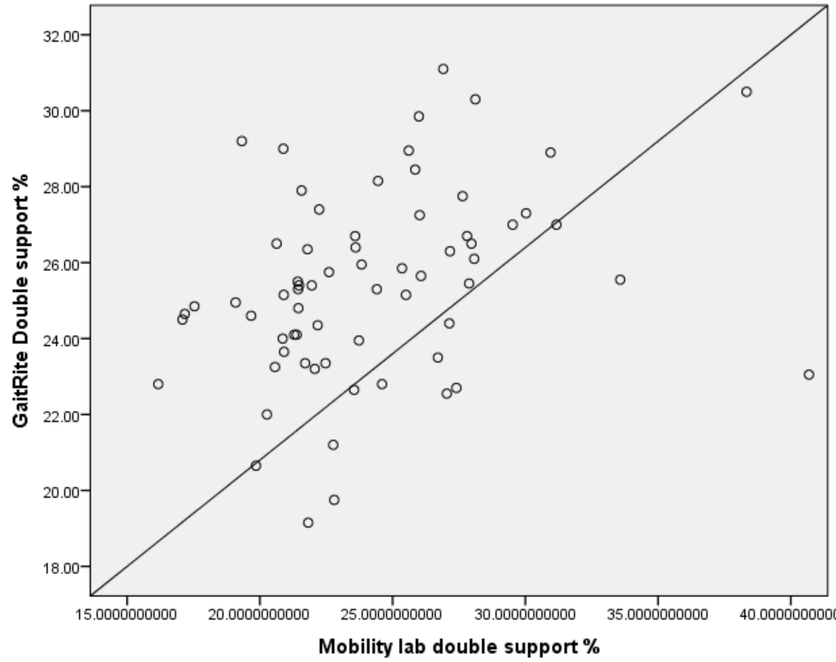


Figure 8. The Pearson Correlation Coefficient of stance % cycle between MobilityLab™ and GAITRite® (r = 0.035; p = 0.778).

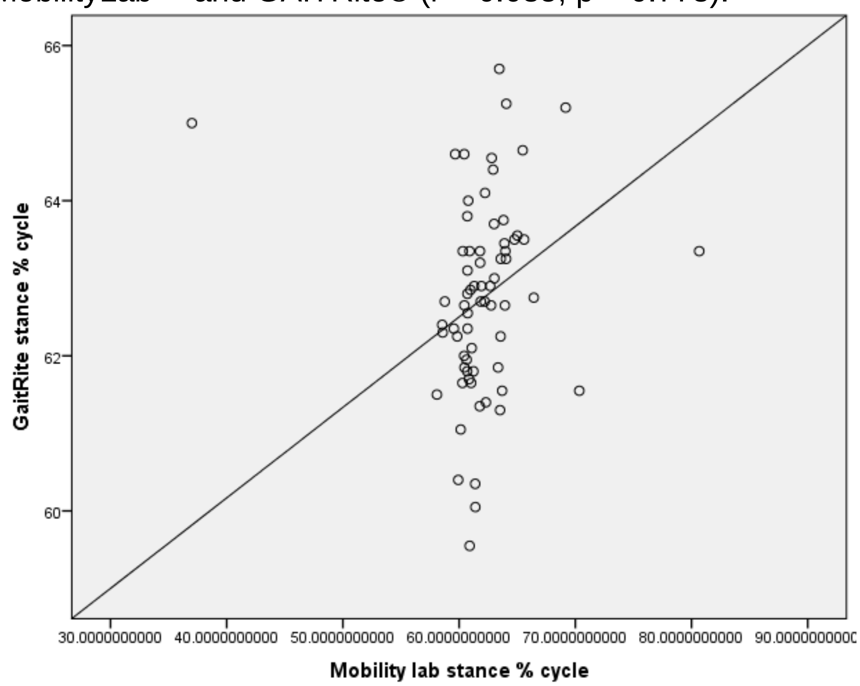
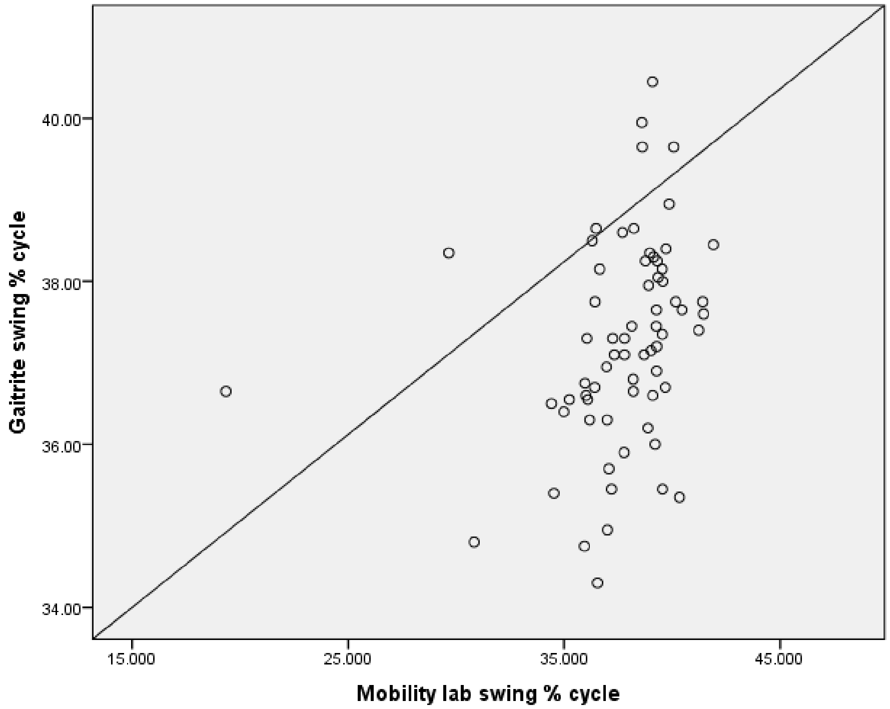


Figure 9. The Pearson Correlation Coefficient of swing % cycle between MobilityLab™ and GAITRite® (r = 0.186; p = 0.128).



APPENDIX C

Scores were circled.

Modified Gait Abnormality Rating Scale (GARS-M)

(VanSwearingen, 1996)

1. Variability--*a measure of inconsistency and arrhythmicity of stepping and/or arm movements:*

0 = fluid and predictably paced limb movements

1 = occasional interruptions (changes in speed) approximately 25% of the time

2 = unpredictability of rhythm approximately 25%-75% of the time

3 = random timing of limb movements

2. Guardedness--*hesitancy, slowness, diminished propulsion, and lack of commitment in stepping and arm swing*

0 = good forward momentum and lack of apprehension in propulsion

1 = center of gravity of head, arms, and trunk (HAT) projects only slightly in front of push-off, but still good arm-leg coordination

2 = HAT held over anterior aspect of foot and some moderate loss of smooth reciprocation

3 = HAT held over rear aspect of stance-phase foot and great tentativeness in stepping

3. Staggering--*sudden and unexpected laterally directed partial losses of balance*

0 = no losses of balance to side

1 = a single lurch to side

2 = two lurches to side

3 = three or more lurches to side

4. Foot contact--*the degree to which heel strikes the ground before the forefoot*

0 = very obvious angle of impact of heel on ground

1 = barely visible contact of heel before forefoot

2 = entire foot lands flat on ground

3 = anterior aspect of foot strikes ground before heel

5. Hip ROM--*the degree of loss of hip range of motion seen during a gait cycle*

0 = obvious angulation of thigh backward during double support (10°)

1 = just barely visible angulation backward from vertical

2 = thigh in line with vertical projection from ground

3 = thigh angled forward from vertical at maximum posterior excursion

6. Shoulder extension--*a measure of the decrease of shoulder range of motion*

0 = clearly seen movement of upper arm anterior (15°) and posterior (20°) to vertical axis of trunk

1 = shoulder flexes slightly anterior to vertical axis

2 = shoulder comes only to vertical axis or slightly posterior to it during flexion

3 = shoulder stays well behind vertical axis during entire excursion

7. Arm-heel-strike synchrony--*the extent to which the contralateral movements of an arm and leg are out of phase*

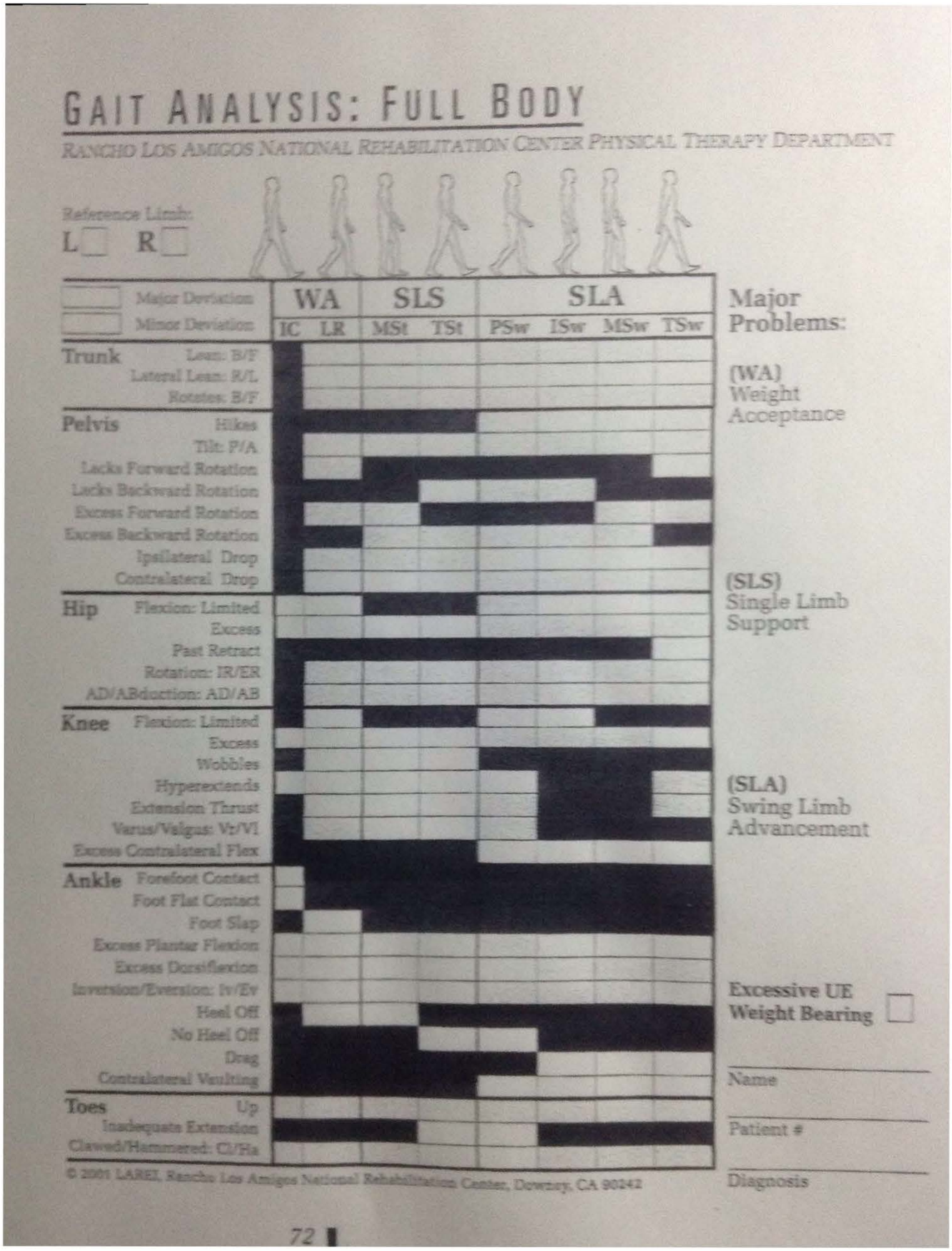
0 = good temporal conjunction of arm and contralateral leg at apex of shoulder and hip excursions all of the time

1 = arm and leg slightly out of phase 25% of the time

2 = arm and leg moderately out of phase 25%-50% of the time

3 = little or no temporal coherence of arm and leg

<u>APPENDIX D</u> – Rancho Los Amigos Observational Gait Analysis



GAIT ANALYSIS: FULL BODY

RANCHO LOS AMIGOS NATIONAL REHABILITATION CENTER PHYSICAL THERAPY DEPARTMENT

Reference Limb:
L ☐ R ☐

☐ Major Deviation / ☐ Minor Deviation	WA		SLS		SLA			
	IC	LR	MSt	TSt	PSw	ISw	MSw	TSw
Trunk Lean: B/F								
Lateral Lean: R/L								
Rotates: B/F								
Pelvis Hikes								
Tilt: P/A								
Lacks Forward Rotation								
Lacks Backward Rotation								
Excess Forward Rotation								
Excess Backward Rotation								
Ipsilateral Drop								
Contralateral Drop								
Hip Flexion: Limited								
Excess								
Past Retract								
Rotation: IR/ER								
AD/ABduction: AD/AB								
Knee Flexion: Limited								
Excess								
Wobbles								
Hyperextends								
Extension Thrust								
Varus/Valgus: Vr/Vl								
Excess Contralateral Flex								
Ankle Forefoot Contact								
Foot Flat Contact								
Foot Slap								
Excess Plantar Flexion								
Excess Dorsiflexion								
Inversion/Eversion: Iv/Ev								
Heel Off								
No Heel Off								
Drag								
Contralateral Vaulting								
Toes Up								
Inadequate Extension								
Clawed/Hammered: Cl/Ha								

Major Problems:

(WA) Weight Acceptance

(SLS) Single Limb Support

(SLA) Swing Limb Advancement

Excessive UE Weight Bearing ☐

Name

Patient #

Diagnosis

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References

1. American with Disabilities Act of 1990, Pub. L.No. 101-336, § 12102, 104 Stat. 328. Available at: http://www.law.cornell.edu/uscode/text/42/12102. Accessed April 19, 2015.

2. Brault MW. Americans with disabilities: 2010. Current Population Reports P70-131. US Census Bureau; Washington, DC. Available at: www.census.gov/prod/2012pubs/p70-131.pdf. Accessed April 19, 2015.

3. Blackwell DL, Lucas JW, Clarke TC. Summary health statistics for U.S. adults: national health interview survey, 2012. *Vital and Health Stat 10.* 2014 Feb;(260):1-160.

4. Office of the Surgeon General (US); Office on Disability (US). The Surgeon General's Call to Action to Improve the Health and Wellness of Persons with Disabilities. Rockville (MD): Office of the Surgeon General (US); 2005. II, Understanding Disability. Available from: http://www.ncbi.nlm.nih.gov/books/NBK44671/. Accessed November 20, 2014.

5. Hicks AL, Ginis KA. Treadmill training after spinal cord injury: it's not just about the walking. *J Rehabil Res Dev*. 2008;45(2):241-8.

6. Brown RL, Turner JR. Physical disability and depression: clarifying racial/ethnic contrasts. *J Aging Health*. 2010 Oct;22(7):977-1000.

7. Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT. Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. *Lancet*. 2012 Jul 21;380(9838):219-29.

8. World Health Organization. International Classification of Functioning, Disability and Health. Geneva: World Health Organization, 2001.

9. Neurology Section of the American Physical therapy association Web site. - http://www.neuropt.org/professional-resources/neurology-section-outcome-measures-recommendations. Accessed April 19, 2015.

10. Gronley JK, Perry J. Gait analysis techniques. Rancho Los Amigos Hospital gait laboratory. *Phys Ther.* 1984 Dec;64(12);1831-8.

11. VanSwearingen JM, Paschal KA, Bonino P, Yang JF. (1996). The Modified Gait Abnormality Rating Scale and recognizing recurrent fall risk of community-dwelling, frail older veterans. *Phys Ther*. 76:994–1002.

12. Guide to Physical therapy Practice 3.0. Alexandria, VA: American Physical Therapy Association; 2014. Available at: http://guidetoptpractice.apta.org/. Accessed April 17, 2015.

13. Gregory CM, Embry A, Perry L, Bowden MG. Quantifying human movement across the continuum of care: From lab to clinic to community. *J Neurosci Methods*. 2014;231:18-21.

14. Mayagoitia RE, Nene AV, Veltink PH. Accelerometer and gyroscope measurement of kinematics: an inexpensive alternative to optimal motion analysis systems. *Journal of Biomechanics.* 2002;35:537-542

15. Randall AL. Nelson M, Akkapeddi S, Levin A, Alexandrescu R. Reliability of measurements of pressures applied on the foot during walking by a computerized insole system. *Arch Phys Med Rehabil*. 2000;81(5):573-578

16. Winstein C, Pate P, Ge T, et al. The physical therapy clinical research network (PTClinResNet): methods, efficacy, and benefits of a rehabilitation research network. *Am J Phys Med Rehabil*. 2008;87(11):937-50.

17. Mancini M, King L, Salarian A, Holstrom L, McNames J, Horak F. Mobility lab to assess balance and gait with synchronized body-worn sensors. *J Bioengineer & Biomedical Sci.* 2012;1:007.

18. Brach JS. VanSwearingen JM. (2002). Physical Impairment and Disability: Relationship to Performance of Activities of Daily Living in Community-Dwelling Older Men. *Physical Therapy* 82:8, 752-761

19. VanSwearingen JM, Paschal KA, Bonino P, Yang JF. (1996). The Modified Gait Abnormality Rating Scale and recognizing recurrent fall risk of community-dwelling, frail older veterans. *Phys Ther*. 76:994–1002.

20. Toro B, Nester C, Farren P. A review of observational gait assessment in clinical practice. *Physiotherapy Theory and Practice.* 2003; 19(3):137-149.

21. Bilney B, Morris M, Webster K. Concurrent validity of the GAITRite® walkway system for quantification of the spatial and temporal parameters of gait. *Gait Posture.* 2003;17:68–74.

22. Baker BJ, Blount KD, Cox DE, Roberts BL. Reliability and validity of the GAITRite system for gait analysis in typically developing children. In: Proceedings of the American Physical Therapy Association Combined Sections Meeting; 2002 Feb 12-16; Boston (MA)

23. Uden C, Besser MP. Test-retest reliability of temporal and spatial gait characteristics measured with an instrumental walkway system (GAITRite). *BMC Musculoskelet Disord.* 2004;5:1-5

24. Viera AJ, Garrett JM. Understanding interobserver agreement: the kappa statistic. *Fam Med.* 2005 May;37(5):360-3.

25. Hallgren KA. Computing inter-rater reliability for observational data: an overview and tutorial. *Tutor Quant Methods Psychol.* 2012;8(1):23-34.

Curriculum Vitae

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Education

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  - 2012-Present: DPT, Doctor of Physical Therapy
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- Brigham Young University
  - 2007-2012: B.S., Business Management

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- Evidence Based Research
- Exercise Physiology
- Orthopedic Principles, Assessment and Rehabilitation
- Neuroanatomy, Physiology and Rehabilitation
- Research Statistics
- Pediatrics
- Prosthetics and Orthotics

Clinical Experience

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  - Outpatient Orthopedic setting
- Healthsouth Rehabilitation Hospital – Mesa, AZ
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  - October 2014 – December 2014
  - Inpatient Acute care setting
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- Evidence Based Research
- Exercise Physiology
- Orthopedic Principles, Assessment and Rehabilitation
- Neuroanatomy, Physiology and Rehabilitation
- Research Statistics
- Pediatrics
- Prosthetics and Orthotics

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    - July 2014 – October 2014
    - Inpatient Rehabilitation setting
- San Luis Sports Therapy – San Luis Obispo, CA
    - October 2014 – December 2014
    - Outpatient Orthopedic setting
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