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Reliability of Center of Pressure Measures for Assessing the Development of Sitting Postural Control in Infants With or at Risk of Cerebral Palsy

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Running head: Reliability of COP in infants with CP

Title: Reliability of center of pressure measures for assessing the development of sitting postural control in infants with or at risk of cerebral palsy.

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Title: Reliability of center of pressure measures for assessing the development of sitting postural control in infants with or at risk of cerebral palsy.

Abstract

Objectives: To establish the test-retest reliability of linear and nonlinear measures, including intra- and inter- session reliability, when used to analyze the center of pressure (COP) time series during the development of infant sitting postural control in infants with or at risk for cerebral palsy (CP).

Design: Longitudinal study

Setting: University hospital laboratory

Participants: Eighteen infants with or at risk for CP (mean age at entry in the study ± standard deviation, 13.1.7 ± 3.6 months).

Interventions: Not applicable

Main Outcome Measures: Infant sitting COP data was recorded for three trials at each session (two sessions for each month within one week) for four consecutive months. The linear COP parameters of root mean square (RMS) and range of sway for both the anterior-posterior (AP) and the medial-lateral (ML) directions, and sway path, were calculated. In addition, the nonlinear parameters of approximate entropy (ApEn), Lyapunov exponent (LyE), and correlation dimension (CoD) for both directions were also calculated. Intra-session and inter-session reliability was computed by the intraclass correlation coefficient (ICC).

Results: Regarding nonlinear measures, LyE showed high intra-session and inter-session ICC values in comparison to all other parameters evaluated. Intra-session and inter-session reliability increased overall in the last two months of the data collections and as sitting posture improved.

Conclusions: Our results suggested that the methodology presented is reliable way of examining the development of sitting postural control in infants with or at risk for CP, and the reliability

results generally parallels values found in sitting postural behavior in typical infants. Therefore, this methodology may be helpful in examining efficacy of therapy protocols directed at advancing sitting postural control in infants with motor developmental delays.

Key Words: Posture; Nonlinear dynamics; Reproducibility of Results; Cerebral palsy; Developmental Disabilities

Abbreviations:

COP – Center of pressure

CP – Cerebral palsy

RMS – Root mean square

AP – Anterior/posterior

ML – Medial/lateral

ApEn – Approximate entropy

LyE – Lyapunov exponent

CoD – Correlation dimension

ICC – Intra class correlation coefficient

Introduction

Cerebral palsy (CP) is defined as a nonprogressive disorder of posture and movement, which is caused by damage to the motor control centers of the developing brain, and can occur pre-, peri- and post-natally[1]. Children with CP have several fundamental limitations in postural control of static and dynamic tasks, such as sitting, standing and walking[2]. In particular, a delay in achieving the first milestone of postural control, which is independent sitting, is one early sign that a child's development is not following a normal course[3]. Disruptions in sitting postural control significantly affect the development of a child, and can limit the ability to develop eventual independent movement[4-6].

A diagnosis of CP is often delayed until the child is over 2 years of age. Initial identification of a developmental problem during early infancy is difficult since current clinical testing methods are not highly specific or sensitive, and some early neurological symptoms may be transient and resolve spontaneously[7]. On the other hand, early intervention is considered essential to take advantage of the plasticity of the developing infant's nervous system for optimal development[8]. Thus, there is a need to identify a quantifiable method that will assess the developing mechanisms of sitting postural control in children with early postural control problems, describe and identify the types of problems to target in early intervention, and help to determine early intervention efficacy.

Postural control can be described using a simple paradigm of sitting and standing on a force platform to measure the center of pressure (COP) to quantify body sway. The organization of posture has been described repeatedly in the literature by the COP[9]. COP data have been used in investigations of postural control during standing in healthy adults during a dual task paradigm[10] and Parkinson's disease patients[11], as well as in healthy young children[12] and children with cerebral palsy[13]. The reliability of this methodology has been examined thoroughly during

standing for both healthy and unhealthy populations. Intraclass correlation coefficient (ICC), which is a statistical method of evaluating reproducibility of results, revealed that COP measures in general produced poor to fair reliability (0.3 to 0.75) under static and dynamic balance tasks[14-17].

Furthermore, in the past few years new concepts and methods for studying postural control have been introduced. Currently, COP data have been evaluated not only with conventional linear measures, which provide an "average" picture and lose the temporal aspect of sitting, but also with nonlinear measures, which describe the temporal organization of the postural sway pattern of sitting[18]. Nonlinear measures can provide new insights in the ways that the nervous system controls the complexity of dynamic balance[19, 20]. Moreover, nonlinear measures unveil different features of the COP data. For example, range and the length of path traced by the COP, which are traditional linear measures, evaluate the quantity of movement variations of the COP during a specific task independently of their order in the distribution. On the other hand, Lyapunov Exponent (LyE) and Approximate Entropy (ApEn), which are nonlinear measures, they are able to capture the temporal component of the movement variation in COP regarding how motor behavior emerges in time. Temporal organization or "structure" can be measures by the extent to which values of COP data emerge in a predictable way[19-22]. The usage of these measures has increased recently because they allow the quantification of constructs such as regularity, complexity, and stability[20].Thus, nonlinear analyses of the COP data as sitting develops can provide a window into the neurological status of the infant with CP, and allow insight into the multifaceted strategies these infants utilize to organize movement and posture.

Recently, the COP methodology has also been utilized to investigate sitting postural control[19,20,23,24]. However, the reliability of COP measures for the evaluation of infant sitting postural control has been identified only for typically developing infants[25]. Specifically, Kyvelidou et al.[25] found that COP measures for the evaluation of infant sitting postural control is a fairly reliable methodology. They examined both linear and nonlinear measures of COP during the development of sitting posture in typically developing infants. They found that both types of measures presented inter-session and intra-session ICC values ranging from poor to good reproducibility, with the last two months of data collection presenting consistently fair to good ICC values[25]. However, the reliability of this methodology for infants with cerebral palsy is currently unknown.

Therefore, the purpose of this study was to establish the reliability of linear and nonlinear measures, including intra- and inter- session reliability, when used to analyze the COP data during the development of sitting postural control in infant with or at risk of CP. Based on the previous reliability data on typical development of infant sitting[25], we hypothesized that the nonlinear tools will be more reliable in assessing development of infant sitting postural control and that reliability measures will increase with development. The identification of the reliability of linear and nonlinear tools from COP data is necessary in order to validate the reliability of the procedure, so that it can then used in the future to assess efficacy of treatment and increments of change over time in children with or at risk for CP. Once this procedure is established, comparisons of the sitting behavior of infants with typical development and infants with cerebral palsy can be made, and be certain that our results are not measurement artifacts but true differences.

Methods

Participants

For the present study we recruited 30 infants with or at risk for CP (mean age at entry in the study ± standard deviation, 13.1.7 ± 3.6 months; gender, 10 males 8 females). The infants were referred from local early intervention programs. The infants were followed from the age where they could exhibit at least 10 sec of independent sitting and for four months after that time. Infants were recruited from employee announcements at the campus of the university. The parents of the infants provided informed consent that was approved by the university human research ethics committee before data collection initiation. The inclusion criteria for entry into the study for the infants with or at risk for CP as well as the exclusion criteria are presented in Table 1. Furthermore, the Gross Motor Function Classification Scale (GMFCS) level as well as the diagnosis that the infants with or at risk for CP received after two years of age is presented in Table 2.

----------Place Tables 1 and 2 around here----------

Experimental design

Each infant participated in nine sessions. The first session and was used to perform the Peabody Gross Motor Scale[26] which is a standardized clinical test[37]. In addition, the child was tested to determine adequate prop sitting skills to begin the study, and to familiarize the family with the procedures used in the study. The other eight sessions were dispersed over a time period of four months. To assure that inter-session measures captured the infants at the same stage of sitting development, the infants were tested twice in one week at each of the four months of the study. Three trials per session were used to determine intra-session reliability (Figure 1). The repeat testing within one week of each month's testing was utilized for the estimation of the inter-session reliability (Figure 1).

----------Place Figure 1 around here----------

Protocol

For all sessions, the infants and the parents were given time to get used to the laboratory environment. Subsequently, they sat on the force platform with their parent in front of them for the data collection. The sessions lasted approximately 30 minutes to one hour. After the force platform was covered with an absorbent pad, which was securely adhered with tape, infants were positioned by their parent on the top of the force platform. The infant was in the sitting position in the middle of the plate when calm (Figure 2). For safety reasons, the investigator and the parent remained at one side and in front of the infant respectively during all data collection. When the child was ready, and was not held by the examiner, COP data were collected continuously while the child attempted to maintain the sitting position control without falling. Once we had collected three trials that were acceptable for our criteria (see below), or until the infants were indicating that they were done, data collections were completed.

----------Place Figure 2 around here----------

From the videotape record we selected three acceptable trials (8.3 seconds each) based on the following criteria: a) infant did not move the arms (not reaching, holding an object, or flapping their arms), b) infant did not vocalize or cry, c) infant was not in the process of falling, d) trunk was not inclined more than 45 degrees to either side, e) not being touched, f) the arm position (propping or not propping) of the infants was noted during the entire trial and only trials that have the infant using a consistent base of support was used.

For the collection of the COP data, infants sat on an AMTI force platform (Advanced Mechanical Technology Inc., Model OR6-7-1000, Watertown, MA), interfaced to a computer

system running Vicon data acquisition software (Lake Forest, CA). The force platform simultaneously measures three force components Fx, Fy, and Fz and three moment components Mx, My, and Mz. The forces and moments are measured by strain gauges attached to load cells at the four corners of the platform. The force plate has a 4450 N (1000 lb) capacity for Fz and a 2225 N (500 lb) capacity for Fx and Fy. The Fz channel has a natural frequency of 480 Hz and Fx and Fy have a natural frequency of 300 Hz. COP data in both the anterior-posterior (AP) and the medial-lateral (ML) directions were acquired through the Vicon software at 240 Hz, in order to be above a factor of ten higher than the highest frequency contained in the signal. No filtering was performed on the data because such a procedure can affect the nonlinear results. Furthermore, video of each trial was collected using two Panasonic recorders (Model 5100 HS) interfaced with a Panasonic Digital AV Mixer (Model WJ-MX30). The cameras were positioned to record a sagittal and a frontal view of the subject. Segments of acceptable (described below) data were analyzed using custom MatLab software (MathWorks, Nantick, MA). The COP data selected allowed for the examination of 2000 data points (8.3 sec times 240 Hz) for each COP direction for each trial. This number is considered adequate for nonlinear analysis[27,28].

Data analysis

Customized MatLab software was utilized to calculate the linear measures from the COP data from the selected trials, using the methodology of Prieto et al.[29] and included root-mean-square (RMS), maximum minus minimum (range) and length of the path traced by the COP (sway path) for the AP and the ML directions. These parameters are all independent of the effect of biomechanical factors such as weight[30], which may changed rapidly during infancy. These linear measures characterized the amount of variability present in the data[18].

Furthermore, three nonlinear measures of variability were calculated from the selected trials:

the approximate entropy (ApEn), the largest Lyapunov exponent (LyE), and the correlation dimension (CoD) for both the AP and the ML directions. Calculation of the nonlinear measures of the variability present in postural sway was performed as presented by Harbourne and Stergiou[19]. Chaos Data Analyzer Professional software[31] was used to calculate the Lyapunov Exponent and the Correlation Dimension. In order to precisely compute these measures, the embedded dimension must be chosen with extreme care. We estimated the embedded dimension by performing the Global False Nearest Neighbor (GFNN) analysis[32,] with the Tools for Dynamics software. The embedded dimension is a depiction of the number of dimensions needed to unfold the attractor of a dynamical system in state space[33]. For the analysis of all COP traces, the same embedding dimension (6) was used even if they had a dimension lower than six. Lastly, for the calculation of the ApEn custom written MATLAB code was used based on the Pincus[34] algorithms.

Statistical Analysis

Intra-session and inter-session reliability was quantified by the intraclass correlation coefficient[35] (ICC). Specifically, a one-way ANOVA model with a random subject effect was used to estimate the intra-session reliability based on data from the first visit of the month for each child (ICC[1,1] in the notation of Shrout and Fleiss[35]). To estimate the inter-session reliability, the averages of the three measurements during each session are analyzed using a one-way ANOVA model with a random subject effect similar to the model for intra-session reliability. In the results section ICC findings are reported based on Rosner[36]. Specifically, an ICC of less than 0.4 indicates poor reproducibility while an ICC between 0.4 and 0.75 indicates fair to good reproducibility. Lastly, an ICC over 0.75 indicates excellent reproducibility.

Results

Linear Parameters

Inter-session ICCs for the linear parameters were between 0.25 and 0.78 (Table 3). The RMS in the AP direction presented the highest ICC value. All linear parameters presented ICC values

ranging from poor to fair to excellent reproducibility. The highest mean ICC value across months was observed for RMS in AP direction. However, the last month of data collections presented consistently fair to good ICCs with the exception of the sway path parameter (Figure 3). RMS and mean range in AP direction showed consistently increasing values in ICCs across months of sitting postural development. However, sway path presented consistently decreasing values in ICCs across months of sitting postural development.

----------Place Table 3 around here----------

----------Place Figure 3 around here----------

Intra-session ICCs for linear parameters were between 0.19 and 0.75 (Table 4). RMS in the AP direction presented the highest ICC value, which suggests excellent reproducibility. All linear parameters presented ICC values ranging from poor to fair to excellent reproducibility. The highest mean ICC value across months was observed for RMS in AP direction. However, the last three data collections, which are included in the third and fourth month sessions, presented consistently fair to good ICCs (Table 4, Figure 4). We can observe that RMS, range and sway path presented consistently increasing values in ICC's across data collections. The above findings are in agreement with the inter-session reliability with the exception of sway path.

----------Place Table 4 around here----------

----------Place Figure 4 around here----------

Nonlinear Parameters

Inter-session ICCs for nonlinear parameters were between 0.16 and 0.78 (Table 5). LyE in the AP direction presented the highest ICC value, which suggests excellent reproducibility. All

nonlinear parameters presented ICC values ranging from poor to fair to excellent reproducibility. The highest mean ICC value across months was observed for LyE in AP direction. However, the last two months of data collections presented alternating fair to good reproducibility (Table 4, Figure 5).

----------Place Table 5 around here----------

----------Place Figure 5 around here----------

Intra-session ICCs for nonlinear parameters were between 0.05 and 0.70 (Table 6). Overall, nonlinear parameters presented ICC values ranging from poor to fair to good reproducibility. The highest mean ICC value across months was observed by ApEn in the AP direction. Furthermore, with the exception of CoD all other nonlinear parameters present fair to good reproducibility across data collections (Figure 6).

----------Place Table 6 around here----------

----------Place Figure 6 around here----------

Discussion

The goal of the present study was to establish the reliability of linear and nonlinear measures, including intra- and inter- session reliability, when utilized to examine the COP data during the development of sitting postural control in infants with or at risk for CP. Based on our previous study[20] , we hypothesized that the linear and nonlinear measures will present different reliability values because they are quantifying different features of the COP data.

Reliability assessment of all linear parameters during sitting posture in infants with or at risk for CP presented inter- and intra- session ICC values ranging from poor, to good, to excellent reproducibility. Similarly to our previous study in the development of sitting postural control in typically developing infants[20], the last two months of data collections presented consistently fair to good ICCs. In contrast the sway path parameter presented decreased values of inter-session reliability across development, while the intra- session ICCs were increased across development. Similarly, reliability assessment of all nonlinear parameters during sitting posture in infants with or at risk for CP presented inter- and intra- session ICC values ranging from poor to good reproducibility. However, the last two months of data collections did not present increased ICC values but were consistently fair to good across development with the exception of CoD in both anterior-posterior and medial-lateral directions. Overall, RMS and LyE presented the highest ICC values compared to all other parameters examined, while the rest of the linear and nonlinear parameters presented acceptable values with the exception of CoD which showed low reproducibility.

Reliability of linear parameters during sitting posture in infants with or at risk for CP paralleled the results of a reliability study of typical infants during the development of sitting[25]. Specifically,

RMS in both directions showed fair to good ICC inter- (0.59 in AP and 0.55 in ML) and intra-session (0.57 in AP and 0.54 in ML) values in infants with or at risk for CP while typical infants showed also fair to good ICC values inter- (0.44 in AP and 0.41 in ML) and intra- session (0.51 in AP and 0.49 in ML) [25]. Similar results were observed in range and sway path in the infants with or at risk for CP and typical infants. Furthermore, standing posture studies in healthy adults[14] and elderly individuals[15, 37] showed similar reliability findings with sitting posture in infants with or at risk for CP. Particularly, the nonlinear measure RMS in AP and ML directions presented fair to good intra-session reproducibility (0.58) during a standing task of healthy elderly individuals[37]. Moreover, intra-session ICC values for the range of COP during standing in healthy adults were fair to good for both the AP and ML directions[16]. However, inter-session reproducibility of linear measure during a standing task of healthy adults presented fair to poor reliability [14]. In addition, children without disabilities exhibited similar ICC values of linear parameters during standing balance tasks to those infants with or at risk for CP during the development of sitting[16]. Intra-session reliability of the Smart Balance Master System, which examines standing posture under different sensory conditions, presented ICC values with a wide range between 0 and 0.79[16]. Lastly, inter-session reliability of Smart Balance Master System ranged between 0.08 to 0.68[16]. Therefore, our present findings are paralle to those reported in the literature from standing posture studies.

With regards to the reproducibility of the nonlinear measures during sitting posture in infants with or at risk for CP presented here, we observed fairly similar results as the reliability data from sitting postural control of typically developing infants[25]. In typical infants, ApEn presented the highest ICC values, while in infants with CP or at risk for CP, LyE presented the highest ICC values. CoD presented poor to moderate ICC values in both groups of infants. In a recent study, a different nonlinear measure, fractal dimension, presented most of the times higher intra-session

reliability than linear measures from COP data during standing in young healthy people, and overall fair to good to excellent reliability values [38]. Analogous to the findings of the present study, ApEn, which is a measure of complexity in the time series, demonstrated fair to good intra-session (>0.50) reproducibility of COP during development of sitting in infants with or at risk for CP.

It is important to note that intra- and inter- session reliability of sitting posture in infants with or at risk for CP improved on the last two months of data collections, especially with the linear measures. Similarly, younger children showed lower ICC values than older children when their COP sway index was investigated during a standing task.

It should be mentioned that inter-subject variability may have influenced our results. Possibly, when infants with CP or at risk for CP entered the study, their sitting behavior was not at the same level. For example, some infants may have entered the study while being able to prop sit, while other infants may did not use the help of their hands at the onset of the study. Presumably, this may be one reason why we observed differences in the sitting behavior in the first two months of sitting development. The usage of stages of sitting instead of months could be used as an alternative to describe sitting postural development. Moreover, the rapid physiological, neuromuscular and psychological changes that infants undergo early on may be the reason why inter-session reliability did not show consistently excellent reproducibility. Therefore, multiple repeated testing distributed across the months of sitting development may allow us to describe more accurately sitting postural control in both typically developing infants and infants with or at risk of CP, since infants are going through a period of rapid growth and change along many interwoven line

In conclusion, we determined that linear and nonlinear description of COP data is a reliable method for assessing the development of sitting postural control in infants with or at risk of CP.

Our results from our linear and nonlinear parameters were similar to those reported in the literature from sitting and standing posture studies. Regarding the linear tools, RMS presented the highest intra- and inter- session ICC values among all other parameters. Regarding the nonlinear tools, LyE presented the highest intra- and inter- session ICC values among all other parameters. In contrast, CoD presented the lowest intra- and inter- session ICC values in comparison to all other parameters examined. Therefore, the presented methodology is not only a reliable tool for the evaluation of sitting postural control using linear and nonlinear tools of COP data, but also a tool to quantifying small amounts of change in the variability patterns of COP data during the development of sitting postural control in infants with or at risk for CP. The present study is extremely important because we can use the presented methodology to assess efficacy of treatment and increments of change over time in children with or at risk for CP. Once this procedure is established we can compare infants with typical development and infants with cerebral palsy and be certain that our results are not measurement artifacts but true differences.. The next step is to determine the validity of these measures in explaining differences in these parameters between infants with typical development and infants with neuromotor disorders. Changes in developing postural control due to learning, maturation and intervention for children with neuromotor disorders can then be examined using measures that better quantify small increments of improving or decreasing motor control. Furthermore, in our future research we plan to explore how COP measures relate with other functional tasks during infant sitting.

Clinical Implications

Infant assessment is notoriously unreliable, with the results being that most testing requires either a scale with many items to obtain a reliable overall picture of the function or behavior of interest, or examination over time to determine problems needing intervention. Because of the

variability in the reliability of the many measures described in this paper, it is likely that a scale using a composite of the variables will better represent the postural behavior of the child reliably.

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Legends

Table 1. Inclusion and exclusion criteria of the study

545 Table 2. Gross Motor Function Classification Scale scores for all infants.

546 Table 3. Inter-session (within a week per month) reliability, as expressed with the Intra-class
547 correlation coefficient (ICC), for all linear parameters.

548 Table 4. Intra-session (within each session) reliability, as expressed with the Intra-class
549 correlation coefficient (ICC), for all linear parameters.

550 Table 5. Inter-session (within a week per month) reliability, as expressed with the Intra-class
551 correlation coefficient (ICC), for all nonlinear parameters

552 Table 6. Intra-session (within each session) reliability, as expressed with the Intra-class
553 correlation coefficient (ICC), for all nonlinear parameters.

554 Figure 1. Schematic representation of inter and intra-session reliability. This procedure was
555 repeated for each month of data collections.

556

557 Figure 2. Position of infant during data collection.

558 Figure 3. Inter-session reliability (ICC) for linear parameters of COP across months. Most linear
559 parameters ICCs are averaging around 0.5 and there is an increasing trend as the infant develops.
560 This is not true for Mean Sway Path where ICC are presenting a decreasing trend across
561 development.

562 Figure 4. Intra-session reliability (ICC) for linear parameters of COP across data collection
563 sessions. All linear parameters ICCs are averaging around 0.5 and there is an increasing trend as
564 the infant develops

Figure 5. Inter-session reliability (ICC) for nonlinear parameters of COP across months. All nonlinear parameters ICCs are averaging lower than 0.5 except of LyE in both directions.

Figure 6. Intra-session reliability (ICC) for nonlinear parameters of COP across data collection sessions. All nonlinear parameters ICCs are averaging around 0.5 except of CoD in both directions.

Table 1.

Inclusion Criteria

Age from five months to two years

Score less than 1.5 SD below the mean for their corrected age on the Peabody Gross Motor Scales

Sitting skills

a) Head control such that when trunk is supported at the mid-trunk, head is maintained for over one minute without bobbing
b) Infant can track an object across midline without losing head control
c) Infant may prop hands on floor or legs to lean on arms, but should not be able to reach and maintain balance in the prop sit position
d) When supported in sitting can reach for toy
e) Can prop on elbows in the prone position for at least 30 seconds

Exclusion Criteria

Age over two years

Score greater than 1.5 SD below the mean for their corrected age on the Peabody Gross Motor Scale

Diagnosed visual impairment

Diagnosed hip dislocation or subluxation greater than 50%

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587 Table 2.

Subject	Diagnosis at 2 years old	Severity	GMFCS
C01	Hypotonic, overall delays	Moderate	3
C02	Developmental Delay	Mild*	
C03	Premature (28 weeks), BPD	Mild*	
C04	Athetoid CP	Moderate	2
C05	Mixed Quadriplegic CP	Moderate	3
C06	Spastic Quadriplegic CP	Severe	4
C07	Right Hemiplegic CP	Mild	1
C08	Noonan's Syndrome	Mild*	
C09	Spastic Hemiplegic CP	Moderate	3
C10	Spastic Quadriplegic CP	Severe	4
C11	Hypotonic; motor delay	Moderate	2
C12	Hypotonic, motor delay	Mild	1
C13	Spastic Diplegia	Moderate	2
C14	Motor delay,hearing impaired	Mild	1
C15	Premature, motor delay	Mild*	
C16	Premature, left hemiplegia	Mild	1
C17	Premature, motor delay	Mild*	
C18	Hypotonia, motor delay	Mild	1

*Diagnosis of CP excluded; children considered to have developmental delay and not CP
BPD=Brochial Pulmonary Dysplasia
GMFCS=Gross Motor Function Classification Scale

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590 Table 3.

Variables	ICC's				
	1st Month	2nd Month	3rd Month	4th Month	Mean
RMS AP	0.44	0.44	0.72	0.78	0.59
RMS ML	0.58	0.70	0.25	0.67	0.55
Range AP	0.40	0.49	0.65	0.69	0.56
Range ML	0.61	0.64	0.35	0.68	0.57
Sway Path	0.46	0.57	0.46	0.25	0.43

Abbreviations: RMS = root mean square, AP = anterior-posterior, ML = medial-lateral

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593 Table 4.

Variables	ICC's								
	1st Month		2nd Month		3rd Month		4th Month		
Sessions	1st	2nd	1st	2nd	1st	2nd	1st	2nd	Mean
RMS AP	0.51	0.42	0.68	0.45	0.59	0.53	0.75	0.61	0.57
RMS ML	0.52	0.20	0.67	0.55	0.71	0.50	0.62	0.57	0.54
Range AP	0.53	0.20	0.64	0.47	0.62	0.32	0.70	0.58	0.51
Range ML	0.50	0.19	0.65	0.52	0.71	0.35	0.66	0.64	0.53
Sway Path	0.44	0.52	0.37	0.65	0.40	0.57	0.57	0.48	0.50

Abbreviations: RMS = root mean square, AP = anterior-posterior, ML = medial-lateral

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596 Table 5.

Variables	ICC's				
	1st Month	2nd Month	3rd Month	4th Month	Mean
ApEn AP	0.57	0.21	0.52	0.44	0.43
ApEn ML	0.56	0.53	0.42	0.28	0.45
LyE AP	0.62	0.60	0.67	0.78	0.67
LyE ML	0.61	0.72	0.31	0.72	0.59
CoD AP	0.69	0.15	0.43	0.29	0.39
CoD ML	0.39	0.43	0.31	0.34	0.37

Abbreviations: RMS = root mean square, AP = anterior-posterior, ML = medial-lateral

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600 Table 6.

Variables	ICC's								
	1st Month		2nd Month		3rd Month		4th Month		
Sessions	1st	2nd	1st	2nd	1st	2nd	1st	2nd	Mean
ApEn AP	0.70	0.63	0.60	0.54	0.63	0.35	0.52	0.65	0.58
ApEn ML	0.54	0.49	0.55	0.57	0.57	0.27	0.59	0.57	0.52
LyE AP	0.64	0.38	0.53	0.29	0.49	0.63	0.58	0.62	0.52
LyE ML	0.48	0.45	0.57	0.57	0.13	0.54	0.49	0.56	0.47
CoD AP	0.47	0.24	0.09	0.42	0.17	0.44	0.42	0.13	0.30
CoD ML	0.42	0.05	0.31	0.44	0.44	0.46	0.43	0.22	0.35

Abbreviations: RMS = root mean square, AP = anterior-posterior, ML = medial-lateral

Figure 1.

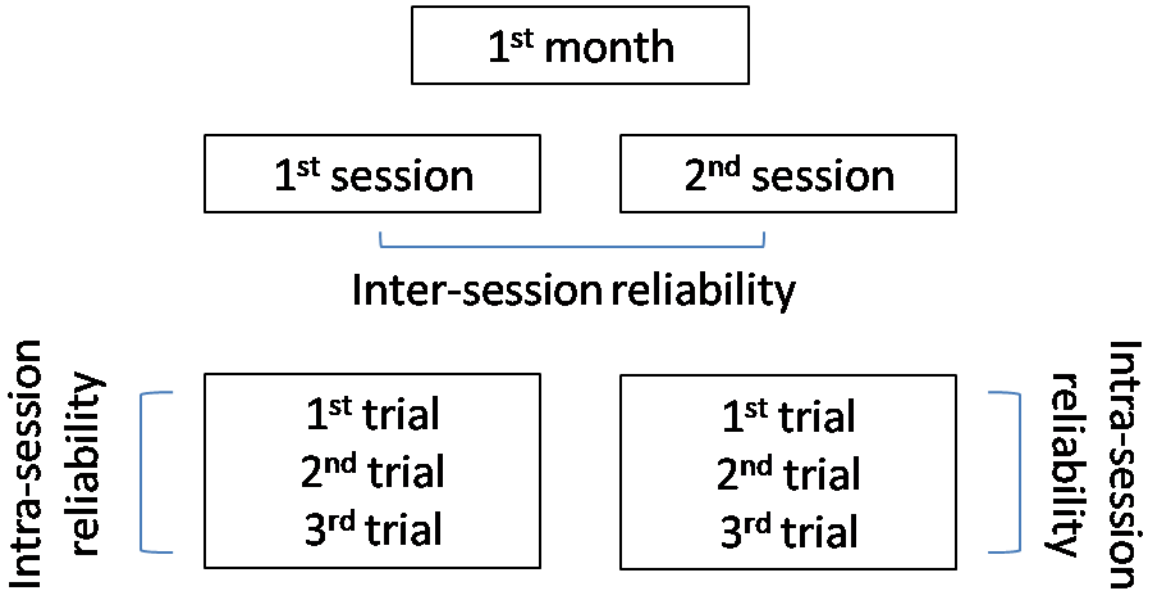
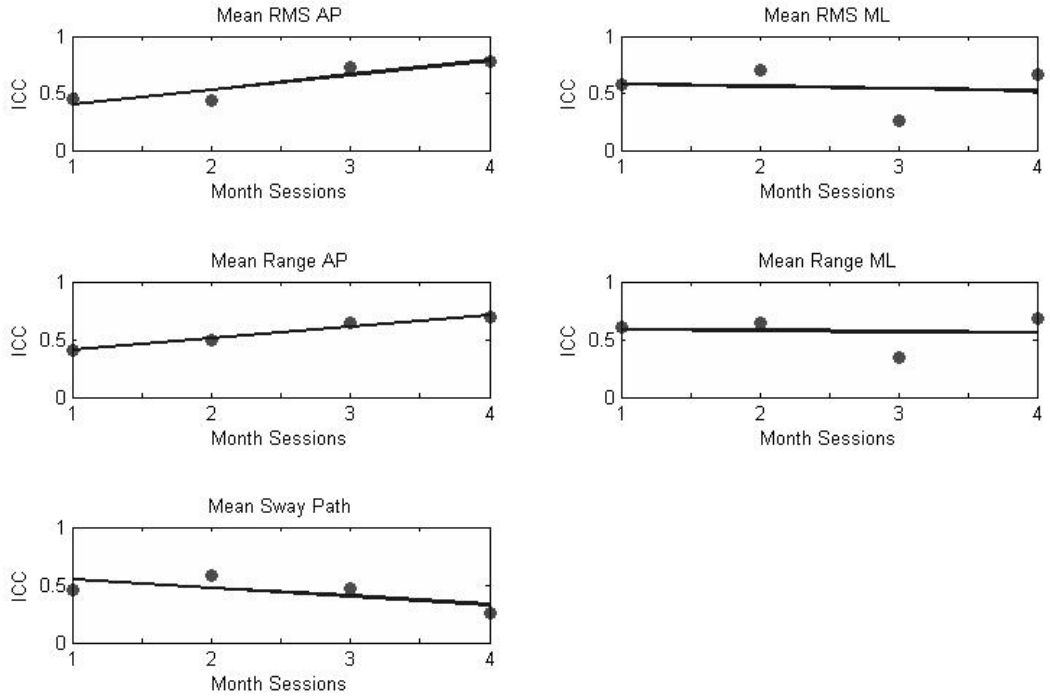

1st month
1st session
2nd session
Inter-session reliability
Intra-session reliability
1st trial
2nd trial
3rd trial
1st trial
2nd trial
3rd trial
Intra-session reliability

Figure 3.



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647 Figure 4.

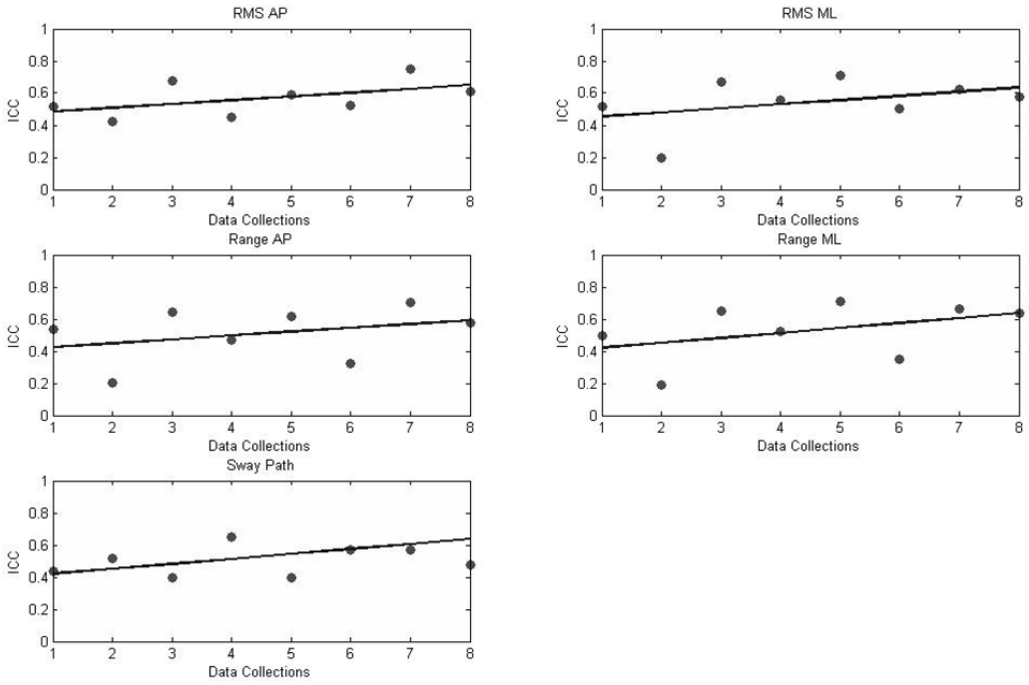
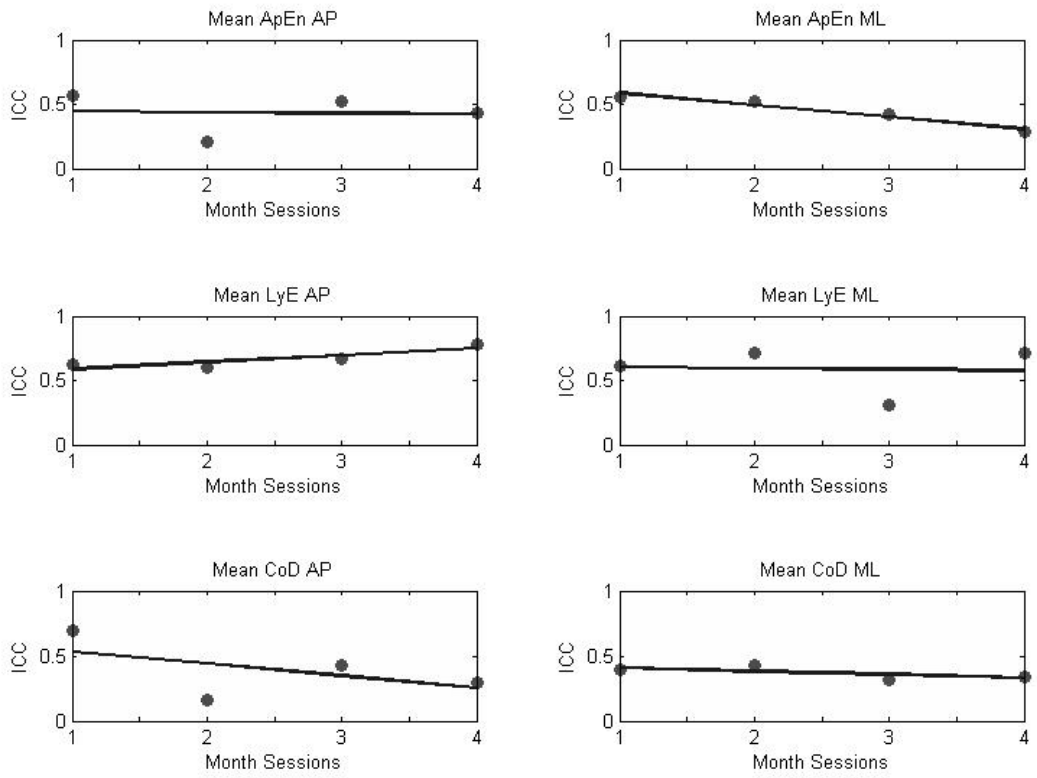

RMS AP
RMS ML
Range AP
Range ML
Sway Path
ICC
Data Collections

Figure 5.



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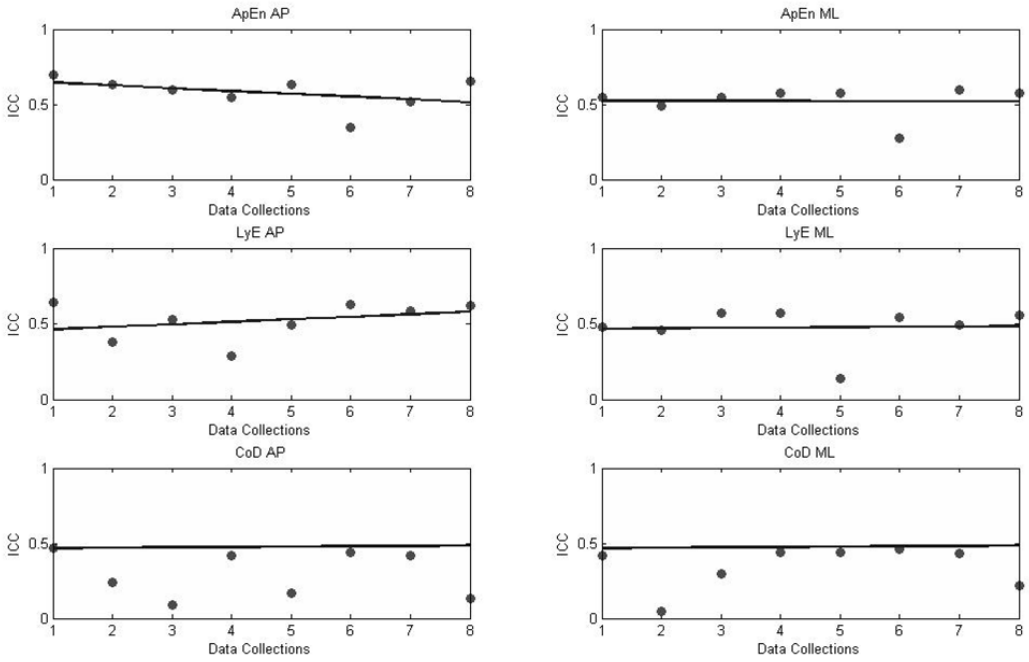
669 Figure 6.



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