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IORgait References

Benedetti MG, Merlo A, Leardini A. (2013) "Inter-laboratory consistency of gait analysis measurements."

Gait Posture. 2013 Sep;38(4):934-9.

The dissemination of gait analysis as a clinical assessment tool requires the results to be consistent, irrespective of the laboratory. In this work a baseline assessment of between site consistency of one healthy subject examined at 7 different laboratories is presented. Anthropometric and spatio-temporal parameters, pelvis and lower limb joint rotations, joint sagittal moments and powers, and ground reaction forces were compared. The consistency between laboratories for single parameters was assessed by the median absolute deviation and maximum difference, for curves by linear regression. Twenty-one lab-to-lab comparisons were performed and averaged. Large differences were found between the characteristics of the laboratories (i.e. motion capture systems and protocols). Different values for the anthropometric parameters were found, with the largest variability for a pelvis measurement. The spatio-temporal parameters were in general consistent. Segment and joint kinematics consistency was in general high (R2>0.90), except for hip and knee joint rotations. The main difference among curves was a vertical shift associated to the corresponding value in the static position. The consistency between joint sagittal moments ranged form R2=0.90 at the ankle to R2=0.66 at the hip, the latter was increasing when comparing separately laboratories using the same protocol. Pattern similarity was good for ankle power but not satisfactory for knee and hip power. The force was found the most consistent, as expected. The differences found were in general lower than the established minimum detectable changes for gait kinematics and kinetics for healthy adults.

Leardini A, Sawacha Z, Paolini G, Ingrosso S, Nativo R, Benedetti MG.(2007) "A new anatomically based protocol for gait analysis in children."

Gait Posture. 2007 Oct;26(4):560-71

Human movement analysis still suffers from the weakness of the currently used protocols for data collection and reduction. Reliable data comparisons and precise functional assessment require anatomically based definitions of the reference axes and frames, and therefore careful identification and tracking of the landmarks. When impaired children are analysed, the marker-set and other measurement procedures have to be minimised to reduce the time of the experiment and ensure patient collaboration. A new protocol is proposed for the analysis of pelvis and lower limb motion obtained as a compromise between these two requirements. A marker-set is proposed which involves the attachment of 22 skin markers, the calibration by a pointer of 6 anatomical landmarks, and the identification of the hip joint centre by a prediction approach. Anatomical reference frames and joint rotations are defined according to current recommendations. The protocol was assessed by analysing a single child in several repetitions by different examiners, and a population of 10 healthy children, mean age 9.7-years-old. The entire analysis was repeated after subtraction of the offset by static posture angles. The minimum and maximum means of the standard deviations from five examiners of the same child were respectively 2.1 degrees in pelvic obliquity and 6.8 degrees in knee rotation. The minimum and maximum means of the standard deviations from the 10 healthy children were 2.1 degrees in pelvic obliquity and 9.6 degrees in knee internal-external rotation. The protocol is feasible and allows 3D anatomical-based measurements of segment and joint motion and data sharing according to current standards.

Ingrosso S, Benedetti MG, Leardini A, Casanelli S, Sforza T, Giannini S.(2009) "GAIT analysis in patients operated with a novel total ankle prosthesis."

Gait Posture. 2009 Aug;30(2):132-7.

A new three-part total ankle prosthesis was designed recently to restore natural joint motion while maintaining full congruity of the articulating surfaces. This was achieved by replicating natural function for the ligaments. Early functional recovery was assessed in the present study in patients who underwent replacement with this prosthesis. This was undertaken using the AOFAS clinical scoring system and gait analysis, performed preoperatively and at 6 and 12 months from surgery. The 10 patients had, at the time of operation, a mean age of 57.4 years (range 45-72), and BMI 25.8 (range 20.4-34.1). A recently proposed protocol for three-dimensional and anatomically based analysis of joint kinematics and kinetics was used. The AOFAS score rose from 44.3 pre-op to 81.5 and 81.0 respectively at 6- and 12-month follow-up, with particular improvement in function. Spatio-temporal parameters improved considerably already at 6 months. More normal patterns and ranges of rotations and moments were observed in the three anatomical planes of the replaced ankle at 6 months and maintained at 12 months. In particular the improvement in dorsi-plantarflexion range in stance was significant, though a limited plantarflexion in swing occurred. EMG revealed a good recovery of physiological activity for the biceps femoris at 12-month follow-up. The new ankle prosthesis contributed to early functional recovery at 6 months, maintained at 1 year.

Conti G, Cristofolini L, Juszczyk M, Leardini A, Viceconti M.(2008) "Comparison of three standard anatomical reference frames for the tibia-fibula complex."

J Biomech. 2008 Dec 5;41(16):3384-9.

Definition of anatomical reference frames is necessary both for in vitro biomechanical testing, and for in vivo human movement analyses. Different reference frames have been proposed in the literature for the lower limb, and in particular for the tibia-fibula complex. The scope of this work was to compare the three most commonly referred proposals (proposed by [Ruff, C.B., Hayes, W.C., 1983. Cross-sectional geometry at Pecos Pueblo femora and tibiae -A biomechanical investigation: I. method and general patterns of variation. American Journal of Physical Anthropology 60, pp. 359-381.], by [Cappozzo, A., Catani, F., Della Croce, U., Leardini, A., 1995. Position and orientation in space of bones during movement: anatomical frame definition and determination. Clinical Biomechanics (Bristol, Avon) 10, pp. 171-178.], and by the Standardization and Terminology Committee of the International Society of Biomechanics, [Wu, G., Siegler, S., Allard, P., Kirtley, C., Leardini, A., Rosenbaum, D., Whittle, M., D'Lima, D.D., Cristofolini, L., Witte, H., Schmid, O., Stokes, I., 2002. ISB recommendation on definitions of joint coordinate system of various joints for reporting of human joint motion-part I: ankle, hip and spine. International Society of Biomechanics. Journal of Biomechanics 35, pp. 543-548.]). These three frames were identified on six cadaveric tibia-fibula specimens based on the relevant anatomical landmarks, using a high-precision digitizer. The intra-operator (ten repetitions) and inter-operator (three operators) repeatability were investigated in terms of reference frame orientation. The three frames had similar intra-operator repeatability. The reference frame proposed by Ruff et al. had a better inter-operator repeatability (this must be put in relation with the original context of interest, i.e. in vitro measurements on dissected bones). The reference frames proposed by Ruff et al. and by ISB had a similar alignment; the frame proposed by Cappozzo et al. was considerably externally rotated and flexed with respect to the other two. Thus, the reference frame proposed by Ruff et al. is preferable when the full bone surface is accessible (typically during in vitro tests). Conversely, no advantage in terms of repeatability seems to exist between the reference frames proposed by Cappozzo et al. and ISB.

Ferrari A, Benedetti MG, Pavan E, Frigo C, Bettinelli D, Rabuffetti M, Crenna P, Leardini A.(2008) "Quantitative comparison of five current protocols in gait analysis."

Gait Posture. 2008 Aug;28(2):207-16

Data collection and reduction procedures, coherently structured in protocols, are necessary in gait analysis to make kinematic and kinetic measurements clinically comprehensible. The current protocols differ considerably for the marker-set and for the biomechanical model implemented. Nevertheless, conventional gait variables are compared without full awareness of these differences. A comparison was made of five worldwide representative protocols by analysing kinematics and kinetics of the trunk, pelvis and lower limbs exactly over the same gait cycles. A single comprehensive arrangement of markers was defined by merging the corresponding five marker-sets. This resulted in 60 markers to be positioned either on the skin or on wands, and in 16 anatomical landmark calibrations to be performed with an instrumented pointer. Two healthy subjects and one patient who had a special two degrees of freedom knee prosthesis implanted were analysed. Data from up-right posture and at least three gait repetitions were collected. Five corresponding experts participated in the data collection and analysed independently the data according to their own procedures. All five protocols showed good intra-protocol repeatability. Joint flexion/extension showed good correlations and a small bias among protocols. Out-of-sagittal plane rotations revealed worse correlations, and in particular knee abduction/adduction had opposite trends. Joint moments compared well, despite the very different methods implemented. The abduction/adduction at the prosthetic knee, which was fully restrained, revealed an erroneous rotation as large as 30 degrees in one protocol. Higher correlations were observed between the protocols with similar biomechanical models, whereas little influence seems to be ascribed to the marker-set.

Manca M, Ferraresi G, Cosma M, Cavazzuti L, Morelli M, Benedetti MG.(2014) “Gait patterns in hemiplegic patients with equinus foot deformity.”

Biomed Res Int. 2014;2014:939316

Equinus deformity of the foot is a common feature of hemiplegia, which impairs the gait pattern of patients. The aim of the present study was to explore the role of ankle-foot deformity in gait impairment. A hierarchical cluster analysis was used to classify the gait patterns of 49 chronic hemiplegic patients with equinus deformity of the foot, based on temporal-distance parameters and joint kinematic measures obtained by an innovative protocol for motion assessment in the sagittal, frontal, and transverse planes, synthesized by parametrical analysis. Cluster analysis identified five subgroups of patients with homogenous levels of dysfunction during gait. Specific joint kinematic abnormalities were found, according to the speed of progression in each cluster. Patients with faster walking were those with less ankle-foot complex impairment or with reduced range of motion of ankle-foot complex, that is with a stiff ankle-foot complex. Slow walking was typical of patients with ankle-foot complex instability (i.e., larger motion in all the planes), severe equinus and hip internal rotation pattern, and patients with hip external rotation pattern. Clustering of gait patterns in these patients is helpful for a better understanding of dysfunction during gait and delivering more targeted treatment.

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