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Test–retest reliability and minimal detectable change of three-dimensional gait analysis in chronic low back pain patients

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ABSTRACT

Background and aim: Three-dimensional gait analysis (3DGA) can provide detailed data on gait impairment in chronic low back pain (CLBP) patients. However, data about reliability and measurement error of 3DGA in this population is lacking. The aim of this study is to investigate test–retest reliability and minimal detectable change of 3DGA in a sample of CLBP patients.
Methods: A test–retest study was conducted with a sample of 14 CLBP patients that underwent two biomechanical gait assessments with an interval of 7.6 ± 1.8 days. Anthropometric and time–distance parameters, as well as peak values for lower limb and trunk joint angles and moments, were computed. Intraclass Correlation Coefficient ($ICC_{3,k}$) and their 95% confidence intervals were calculated. Standard error of measurement (SEM), minimal detectable change (MDC) and limits of agreement (LOA) were also estimated.
Results: The obtained ICC values demonstrate high test–retest reliability for most joint angles, with low SEM (<2.5°) values. Although joint moments showed lower reliability than joint angles, the majority of the ICCs were above 0.7 and the SEM and MDC values were low (≤0.06 N m/kg and ≤0.18 N m/kg). Bland–Altman plots with 95% LOA revealed a good agreement and time–distance parameters were all highly repeatable (ICCs > 0.86).
Conclusions: The results of this study show high test–retest reliability for lower limb and trunk joint angles, and time–distance parameters during gait in CLBP individuals, together with a low measurement error. These results also support the use of this method in clinical assessments of CLBP patients' gait patterns.

1. Introduction

Chronic Low back pain (CLBP) is a common health condition in western industrialized countries with an estimated prevalence of 20.1 ± 9.8% [1]. Patients often report difficulties during daily activities, such as gait. Studies have reported that gait coordination is changed in CLBP patients: they walk slower, take shorter steps and have asymmetric step lengths when compared with their healthy peers [2,3]. Chronic low back pain patients also have difficulty in moving from pelvis-trunk in-phase to anti-phase (pelvis and trunk moving in the same or in opposite directions, respectively) as walking speed increases [4] and consequently show lower variability of trunk rotations, possibly adopting a protective movement strategy to diminish pain [5].

In clinical settings, gait evaluation in CLBP patients is frequently carried out by observation and functional tests [6], or is included in specific disability questionnaires [7], which only provide limited information. In contrast, although time consuming, three-dimensional gait analysis (3DGA) can provide detailed quantitative data concerning gait impairment [8]. As an advantage in CLBP patients,

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3D instruments can obtain real-time information on 3D lumbar spine kinematics and kinetics without any known risk to the patients [9]. Thus, 3DGA can assist in reaching clinical functional diagnoses and can be useful to evaluate the outcome of therapeutic interventions [9]. However, as with any analysis tool, reliability and measurement error emerge as critical factors in its applicability to clinical decision-making [10]. Since low reliability in clinical research may lead to underestimation or failure to detect significant effect sizes [11], we have to strive for good reliability. In addition, knowledge of the error's magnitude can minimize the risk of over-interpreting small differences as meaningful [12] and contribute to the certainty that a measured intervention effect exceeds the measurement error.

Data on reliability and measurement error of 3DGA in CLBP patients is lacking, although evidence that clinically acceptable errors are possible in 3DGA in healthy individuals and in patients with cerebral palsy or stroke do exist [11]. The few studies that evaluated reliability and measurement error of 3D spinal motion analysis in CLBP patients [9,13] focused on simple activities and are difficult to interpret due to incomplete reporting of the studies' populations, testing protocol, statistics and data presentation [13]. Since reliability of measurement tools can be population [14] and task specific, the aim of this study was to investigate test–retest reliability and minimal detectable change of 3D gait analysis in a sample of CLBP patients.

2. Materials and methods

2.1. Study design

A prospective (within assessor) test–retest study was conducted.

2.2. Participants

A convenience sample of 23 CLBP patients was recruited from community and outpatient clinics to participate in a 12-week prospective study according to a standardized recruitment protocol. First, physiotherapists from the research team and outpatient clinics carried out patient recruitment based on predefined inclusion/exclusion criteria. Patients were considered eligible if they were aged between 18 and 65 years, and had low back pain (LBP), with or without referred leg pain, for at least 12 weeks [15] or recurrent LBP [16]. Eligible patients were screened for evidence of serious low back pain pathology and were excluded if they had clinical signs of infection, tumor, osteoporosis, fracture, structural deformity, inflammatory disorder (e.g. ankylosing spondylitis), radicular syndrome, cauda equine syndrome, or if they had undergone back or lower limb surgery or a conservative treatment in the prior 12 and 6 months, respectively. Pregnant women were also excluded. After this screening, 14 of the 23 patients agreed to perform two consecutive assessments with a mean interval of 7 days.

The local Ethics Committee approved the study. All the participants were informed of the procedures and risks of the study and signed an informed consent.

2.3. Procedures

Gait analysis was performed twice with an interval of 6 to 11 days (7.6 ± 1.8). This time interval was considered long enough to avoid assessor memory bias and short enough to avoid a change in patients' gait pattern or clinical condition [10]. On the first visit to the laboratory, participants' clinical history was reviewed and a standard physical examination focused on lumbar spine and lower limbs was performed. This was complemented with the measurement of body mass and height. Segments' length was obtained using the respective proximal and distal anatomical landmarks collected during the static trial described below. For pelvis, anterior and posterior superior iliac spine (ASIS and PSIS) markers were used. To assure participants' clinical stability between test and retest sessions, pain intensity and disability were assessed using the Numerical Rating Scale—(NRS) and the Quebec Back Pain Disability Scale (QBPDS), respectively. Details regarding the psychometric properties of these measurement tools can be found elsewhere [17]).

Finally, gait data was collected using a 13-camera opto-electronic system (Oqus 300, Qualisys AB, Gothenburg, Sweden) synchronized in time and space with two Kistler (Kistler Group, Winterthur, Switzerland) and one AMTI (Advanced Mechanical Technology, Inc Watertown, USA) force platforms at 200 Hz. The marker set used was based on previous reports [18,19] (see supplementary material). After a static trial, participants were instructed to walk barefoot at their preferred velocity, continuously and during short periods of time (1–2 min). A familiarization trial was performed before data collection. Each participant was assessed at the same time of the day to minimize the effects of diurnal variations in joint mechanics. All the procedures were carried out by the same assessor.

2.4. Data processing

Considering the natural variability in kinematic and kinetic gait parameters, 10 cycles were selected [20]. Cycles were extracted using Qualysis Track Manager (v2.8 build 1554, Qualisys AB, Gothenburg, Sweden) and exported to be processed under Visual 3D software (v5.01.10, C-Motion, Inc, Rockville, USA).

A 9-segment model (feet, legs, thighs, pelvis, lumbar and thoracic spine) was built for each participant [18,19]. Each segment was considered to be independent and to have 6 degrees of freedom (segment optimization (SO) method) [21]. Lower limb segment masses were determined according to Dempster [22] while the remaining inertial parameters were computed based on Hanavan [23]. Lumbar and thoracic inertial parameters were computed according to Pearsall, Reid and Livingston [24]. The ankle and knee joint centers were defined as the midpoint of the tibia malleoli and as the midpoint of the femur epicondyles, respectively [25]. The hip joint centers were computed using the pelvis markers, according to published regression equations [26]. The lumbar joint center was defined through a virtual marker created along the distance connecting the L5-S1 marker and the midpoint between the two ASIS markers [18], projected from the T12-L1 joint center. The T12-L1 joint center was defined using a virtual marker projected from the midpoint of the markers placed bilaterally on the ribcage at the T12-L1 joint space level onto the thorax longitudinal axis. The proximal end of this axis was defined as the midpoint between the suprasternal notch and the second thoracic vertebra, while the distal end was defined as the midpoint between the xiphoid process and the inferior angles of most caudal points of the two scapulae. For the pelvis a second LCS was created, based on the CODA pelvis Model [25], in order to achieve a more clinically recognizable pelvic tilt (sagittal plane). All the local coordinate systems (LCS) were defined in accordance with Robertson et al. [25].

A Woltring cross-validity quintic spline routine [27] was used to filter both kinematic and kinetic data. Lower limb and trunk joint angles (using a XYZ Cardan sequence) and moments (determined through inverse dynamics and normalized to subjects' body mass) were computed and expressed relatively to the proximal segment. Data were normalized to 100% stride cycle and peak values for lower limb and trunk joint angles and moments, as well as time–distance parameters, were computed for each cycle and averaged for each subject.