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Reliability and minimal detectable change of gait kinematics in people who are hypermobile

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ABSTRACT

Objective: To evaluate intra- and inter-session reliability of gait data in hypermobile and normal adults, and from this, determine the minimum detectable change (MDC) through 3D gait analysis (GA) measurement.

Methods: Thirteen people with normal flexibility (Beighton score 0.82 ± 1.2) and 14 hypermobile people (Beighton score 5.6 ± 1.6) completed three separate GA sessions. Lower limb joint kinematics were recorded in three planes of motion. Intra- and inter-session variability was calculated and compared using single factor ANOVA. MDC at 95% confidence level was calculated for the hypermobile cohort.

Results: There was no significant difference between hypermobile and normal flexibility adults in intra- or inter-session variability for any parameters measured. For both groups, mean intra-session variability was under 2.0° for all joints in all three planes. Inter-session variability was greater; sagittal plane joint angles were most reliable, showing less than 3.0° variability for all joints. Frontal plane variability was below 3.5°. Highest variability was seen in internal/external rotation angles, with hip, knee and ankle showing 4.6°, 5.1° and 3.2° variability respectively. These reliability values are reflected in MDC results, with pelvis and sagittal plane joint angles showing the lowest MDCs.

Conclusions: In hypermobile people, 3DGA kinematic parameters are repeatable. Hypermobile people's joint laxity does not affect variability of their kinematic gait analysis measures. The results will help guide future clinical trial design; future work should ensure that differences expected to be observed are measurable, and exceed the MDC for a given parameter.

1. Introduction

A joint is considered hypermobile when it exhibits a range of motion greater than expected for a given age, ethnicity or gender [1]. Many people have hypermobility in multiple joints, a condition called Generalised Joint Hypermobility (GJH). Commonly, the Beighton score is used to classify people as hypermobile [2]; up to 9 points are accrued depending on performance of certain movements, and generally a score of 4 or more is considered hypermobile. Incidence of GJH varies with age, gender and ethnicity [3]. In the UK GJH is common; a recent population survey found that 18% of people are classed as hypermobile [4]. Whilst GJH can be asymptomatic and may even be an asset, for example in performing arts [1], it also has a symptomatic counterpart; Joint Hypermobility Syndrome (JHS). This is far less prevalent and is considered part of a range of heritable disorders of connective tissue, which include Ehlers Danlos syndrome, Marfan syndrome, and Osteogenesis imperfecta. Pain is the most common JHS symptom [5], which may be caused by differences in movement, with greater flexibility putting more strain on joints [6].

Three dimensional gait analysis (3DGA) has been used to investigate differences in gait between people with GJH, JHS and normal flexibility participants [7–12]. Although these studies have found differences between normal, GJH and/or JHS gait, these differences have not been consistent [13].

Key to interpreting 3DGA is understanding variability and reliability of gait parameters [14]. If the reliability of gait parameters is unknown, relatively small differences may be considered significant, or alternatively actual differences may be obscured by error [3]. Variability in 3DGA can arise from intrinsic and extrinsic sources. Intrinsic variability is a person's natural gait variability, and is measured by intra-session repeatability (a subject's stride to stride variability during one 3DGA session).

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Extrinsic variability arises from methodological sources, for example errors in palpation, anthropometric measurements, and joint centre determination. Extrinsic reliability is measured by inter-session variability (the variability between separate 3DGA sessions) [3]. Intra- and inter-session reliability of lower limb 3D kinematics during gait in normal populations is well documented, and has been measured in other patient groups with movement disorders; cerebral palsy [15], stroke [16], hemiplegia [17], and in spastic children [18]. As the variability of hypermobile gait is unknown, it is difficult to interpret results of current 3DGA studies. Knowing the reliability of 3DGA measurements in hypermobile people is particularly relevant given that characteristics of hypermobility may affect measurement repeatability. For example, hypermobile joints have a greater range of motion than normal, and skin of hypermobile people tends to be hyperextensible [1], which may affect how skin slides over the skeleton; a significant cause of error in 3DGA [19].

Typically 3DGA aims to differentiate between populations (i.e. normal/abnormal gait), to differentiate an individual from a normal population, or to measure change in gait over time, for example when assessing physiotherapy treatment [20]. Physiotherapy is a common treatment for treating JHS, although further studies are required to determine what is effective [21]. 3DGA could be used as an outcome measure for assessment, as is the case for stroke [22] and senior's fall prevention [23]. For this to be the case, as well as understanding variability and the measurement error, it is necessary to know the magnitude by which a gait variable must change, in order to be sure the change is real and not due to measurement error [24]. To date this minimal detectable change (MDC) and 3DGA reliability in hypermobile people has not been studied. Quantifying these parameters would (1) aid the interpretation of existing and future studies of hypermobile gait, and (2) provide guidance on what 3DGA outcome measures can be used with confidence, to ensure that the change observed during/after an intervention, is greater than the MDC. Therefore, the objective of this study was to measure the intra- and inter-session reliability of gait kinematics in GJH participants compared to people with normal flexibility, and from this to calculate the MDCs for relevant gait parameters.

2. Methods

2.1. Subjects

Ethical approval was granted from NRES London-West Ethics Committee. Informed, written consent was obtained from all participants. Inclusion criteria were ambulatory people aged 18–55 years, with the upper age-limit specified in order to limit occurrence of osteoarthritis. Exclusion criteria were designed to remove participants with any condition that may affect their gait, these included lower-limb pain, lower-limb surgery, JHS (classified using the Brighton criteria), and any other neuromuscular condition. A priori testing indicated a sample size of 13 in each group was required to reach sufficient power ($\beta = 0.2$). Twenty seven participants were recruited; 14 hypermobile people (Beighton score $\geq$4) and 13 with normal flexibility (Beighton Score $<$4).

2.2. Lower limb model

In 3DGA misplacement of reflective markers can cause error in the measurement of kinematic parameters [25]. It follows therefore that a standardised placement protocol and a researcher able to place markers consistently will reduce error. All markers were placed by the same researcher (AB). Prior to this study AB gained experience in motion analysis during a 6-month project. For the purposes of this study AB underwent training by an experienced (28 years) senior clinical specialist physiotherapist (CA) to identify relevant anatomical landmarks by palpation. In addition, training was given using human cadavers to gain knowledge of underlying anatomy. To minimise error standardised placement procedures were developed (Table 1).

Table 1
Marker placement details.

Marker	Placement
Posterior superior iliac spine	Most prominent bony process
Anterior superior iliac spine	Most prominent bony process
Lateral femoral epicondyle	Mid-point between most prominent anterior and posterior surface
Medial femoral epicondyle	Mid-point between most prominent anterior and posterior surface
Lateral tibial condyle	Mid-point between most prominent anterior and posterior surface, just below the joint line
Medial tibial condyle	Mid-point between most prominent anterior and posterior surface, just below the joint line
Lateral malleolus	Most prominent bony point
Medial malleolus	Most prominent bony point
Calcaneus	Mid-point between the medial and lateral edge, just above fat pad
Head of 1st metatarsal	Most superior surface
Head of 5th metatarsal	Most superior surface

A customised biomechanical model capable of measuring each segment in 6 degrees of freedom was used. The CODA pelvis (Charnwod Dynamics Ltd., UK) was used to estimate hip joint centre position. The femoral coordinate system was defined using the knee joint centre (mid-point between lateral and medial femoral epicondyle markers) as the origin, *y*-axis as the line passing from knee joint centre to hip joint centre, *z*-axis following the line joining medial and lateral femoral epicondyle markers (positive laterally in the right femur and medially in left femur) and orthogonal to the *y*-axis, and finally an *x*-axis as orthogonal to both *y* and *z*-axes (following a right-hand coordinate system). The shank origin was defined as the mid-point between medial and lateral tibial condyle markers, *y*-axis as the line passing from the ankle joint centre (mid-point between medial and lateral malleolus markers) to the origin, *z*-axis along the line joining lateral and medial tibia condyle markers (positive laterally in the right shank and medially in left) and orthogonal to the *y*-axis, and the *x*-axis orthogonal to the *y* and *z* axes. The foot coordinate system was defined using the ankle joint centre as the origin, a *y*-axis as the line from the mid-point between the head of the first and fifth metatarsals, a *z*-axis following the line between the medial and lateral malleolus and orthogonal to the *z*-axis, and finally an *x*-axis orthogonal to the *y* and *z* axes. Clusters of four markers were placed on lateral aspects of each thigh and shank. In a static trial, the position of the femoral epicondyle markers was measured relative to the thigh cluster, and similarly tibia condyle markers measured relative to the shank cluster. For dynamic trials the knee markers were removed, and position of markers inferred from the thigh and shank clusters. ISB recommended coordinate frames and Euler rotation sequence were used to determine joint rotation angles [26]. VICON Nexus and Bodybuilder software (Oxford Metrics Ltd., Oxford, UK) were used to compute joint angles.

2.3. Testing procedure and data analysis

Subjects were asked to walk unshod along a 6 m walkway with two force plates (Kistler Instruments Corp., Amherst, USA) embedded. For analysis five dominant limb strides were used, from foot strike to ipsilateral foot strike. The force plates were used to determine initial contact, toe off was determined using the method proposed by O'Connor et al. [27]. Trials were recorded