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Review

Relationship and significance of gait deviations associated with limb length discrepancy: A systematic review

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ABSTRACT

Controversy still exists as to the clinical significance of leg length discrepancy (LLD) in spite of the fact that further evidence has been emerging regarding the relationship between several clinical conditions and LLD. The objectives of our study were to review the available research with regard to LLD as a cause of clinically significant gait deviations, to determine if there is a relationship between the magnitude of LLD and the presence of gait deviations and to identify the most common gait deviations associated with LLD. In line with the PRISMA guidelines, a literature search was carried out throughout the Medline, CINAHL and EMBASE databases. Twelve articles met the predetermined inclusion criteria and were included in the review. Quality assessment using the Methodological Index for Non-Randomized Studies (MINORS) scale was completed for all included studies. Two main methodologies were found in 4 studies evaluating gait asymmetry in patients or healthy participants with anatomic LLD and 8 studies evaluating gait deviations while simulating LLD by employing artificial lifts of 1–5 cm on healthy subjects. A significant relationship was found between anatomic LLD and gait deviation. Evidence suggests that gait deviations may occur with discrepancies of > 1 cm, with greater impact seen as the discrepancy increases. Compensatory strategies were found to occur in both the shorter and longer limb, throughout the lower limb. As the discrepancy increases, more compensatory strategies occur. Sagittal plane deviations seem to be the most effective deviations, although, frontal plane compensations also occur in the pelvis, hip and foot.

1. Introduction

Leg length discrepancy (LLD) has been a controversial issue amongst researchers and clinicians for many years. There is a negligible consensus as to its many aspects, including the extent of its clinical significance, prevalence, reliability, validity of measuring methods, effect on function and its role in various neuromusculoskeletal dysfunctions [1].

Anatomic LLD, defined as structural deformities originating from true bony leg length differences [2] is the anatomical difference between the lengths of the two limbs from the femoral head to the distal tibia. LLD can be congenital or acquired. Congenital conditions include mild developmental abnormalities found at birth or childhood and/or various abnormal developmental disorders. Acquired conditions include trauma, fractures, orthopedic degenerative diseases and surgical disorders such as joint replacement.

LLD can also be due to a functional deformity originating from an abnormal hip, knee, ankle or foot movements in each of the three planes of motion [3]. Functional LLD is defined as an asymmetrical leg length, not necessarily resulting from a true bony length difference and may be caused by an alteration of lower limb mechanics, such as joint contracture, static or dynamic mechanical axis malalignment, muscle weakness or shortening. LLD may cause significant lower limb malalignment. When assessing many orthopedic disorders, an abnormal biomechanical factor is usually found. Consequently, many pathological conditions and symptoms might be an outcome of LLD.

Studies have shown anatomic LLD to be very common, occurring in up to 70% of the population, with a discrepancy of > 2 cm affecting at least one out of every 1000 people [4]. A systematic review evaluating the prevalence of LLD, by using radiographic measurements, revealed that 90% of the normal population have some differences in bony leg length, with 20% affected by a variance of > 9 mm [5].

It has been previously proposed that LLD, as high as 25 mm, does not have a damaging effect on function [6–8]. No correlation was found between a LLD of 5 mm to > 35 mm and back pain or pain provoking tests among military training participants [6]. However, this was based on a clinical standing measurement method, with a weak 64% agreement between examiners, with most participants exhibiting < 5 mm

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discrepancy.

Gross [7] concluded that anatomic LLD as high as 25 mm, measured by supine orthoroentgenograms, did not affect the running ability of 35 marathon runners, in spite of the fact that 28 runners presented with a discrepancy of only up to 9 mm and 7 runners with a difference of 10–25 mm, and they were also symptomatic [7]. Gross [8], in another study, concluded that there was hardly any indication for equalization of discrepancies < 20 mm, since the patients' functions were unaffected with a discrepancy ranging from 15 mm to > 35 mm measured by orthoroentgenography. However, these results might be inaccurate since several clinical factors were probably present in his patients diagnosed with significant orthopedic and neurological disorders that could lead to an asymmetrical functional ability. It would be most difficult to evaluate the effect of LLD only on their function.

On the other hand, LLD has been found to be a significant factor in several pathological and physiological conditions which in turn affect function and quality of life [9,10]. An association between clinically measured LLD and foot pathologies [11], abnormal weight bearing associated with chronic LBP and sciatica [12], functional scoliosis in children [13], back injuries among runners [14], a higher incidence of stress fractures and running injuries in the lower extremities of athletes [15] have been found in several studies. Others observed an association between radiographically measured LLD and abnormal foot biomechanics [16], low back pain [17], osteoarthritis of the knee [18], impaired functional outcomes and patient satisfaction after a total hip replacement [10].

The controversy in the literature as to the effect and role that LLD plays in several pathological conditions is due to poor reliability and validity of measurement methods. In addition, it is impossible to narrow down the effect LLD has on pathological conditions when several abnormal biomechanical findings are also present.

Various imaging techniques have been used to measure anatomic LLD [18,19]. Radiography is considered the gold standard with established techniques including full limb radiographs, scanograms and computerized digital radiographs. In addition, computerized tomography (CT) is still considered one of the most precise measurements due to its high sensitivity and relatively low radiographic exposure [20]. This method is highly reliable and valid but is expensive and exposes the subject to radiation, thus, impractical to use in a clinical setting. Although a full limb radiograph is subject to parallax error, measuring from the femoral head to the ankle, is still the method most commonly used due to its functional advantage of being performed while in a standing position.

Clinically, two methods are used to measure LLD: the direct method which measures the distance between two anatomical points while lying in a supine position (using a tape measure) and the indirect method measuring LLD in a standing position, where lifts are used to level the pelvis, preferably using a pelvic leveling device [21]. The height of the lifts needed to level the pelvis is the difference in leg length. The indirect method takes into account functional factors such as the foot, knee and hip position. However, one disadvantage of this method is that a false positive can result when asymmetrical loading of the legs occur [22]. There are still differences of opinion in the literature as to the reliability and validity of these methods; some authors favor the direct method, others, the indirect method. This dispute can be attributed to several potential sources of error such as the difficulty of palpating bony landmarks, anatomical bony asymmetry, bony anomalies of the ASIS and malleoli, excess soft tissue due to overweight, differences in leg circumference and angular deformities.

The different clinical and imaging methods used to measure LLD and the inconsistency in the measuring methods can account for the disagreement in the literature regarding the clinical significance of LLD and amount of LLD that should be addressed.

This paper focuses on a unique important perspective of LLD. The measuring aspect or treatment approach for LLD and its correlation to symptoms are not within the scope of this study. Our goals were to review the available research and answer the following queries: 1. What is known regarding LLD as a cause of clinically significant gait deviations? 2. What is the relationship between the magnitude of LLD and the presence of gait deviations? 3. What are the most common gait deviations associated with LLD?

2. Methods

A systematic review was conducted according to the PRISMA guidelines. A search in the following databases was performed to identify references published between January 2000 and December 2016: Medline (PubMed), CINAHL and EMBASE (OVID). Our search terms included gait or walking combined with the terms leg length discrepancy, leg length inequality or leg length asymmetry. Both researchers (SK and EC) independently screened the titles, abstracts and full papers against the inclusion/exclusion criteria. No disagreements were found and any mild differences were resolved by a consensus discussion. Complete paper copies of all included studies were retrieved. Also included were relevant papers listed as references in retrieved articles. The Methodological Index for Non-Randomized Studies (MINORS) instrument [23] was used to appraise and determine the quality of the studies by both authors in a combined session.

2.1. Inclusions and exclusion criteria

Studies chosen reported assessed gait characteristics in terms of kinematics, kinetics and muscle activity. Participants included were patients diagnosed with only anatomic LLD or healthy participants found to have anatomic LLD. In addition, studies simulating LLD by external lifts on healthy participants and assessing their effect on gait characteristics were also included. Studies were excluded if gait was evaluated on patients diagnosed with LLD as a secondary or an additional condition. Any studies evaluating the effect of LLD or the treatment of LLD on symptoms and other biomechanical findings, other than gait deviations, were excluded.

2.2. Data analysis

All data extracted from the studies included in this review were performed by both authors and if any discrepancies were found, both authors reexamined their conclusions and reached a consensus. The data were placed into tables and included participants, leg length measurement methods, anatomic discrepancy, intervention used to simulate LLD, outcome measurements and results. The effect of anatomic LLD on gait deviations is shown in Table 1 and the effect of simulated LLD by an external lift on gait deviations is shown in Table 2.

3. Results

The database search resulted in compilation of 2661 records. Following the removal of duplicate studies, review articles and studies that did not meet the inclusion criteria, 20 articles were selected for full text screening, of which 10 met the inclusion criteria with an additional 2 records included from hand searches of reference lists. A total of 12 studies were subsequently used in the analysis (Fig. 1). Four research investigations measured the effect of anatomic LLD on gait deviations and 8 reported on the effect of simulated LLD by a lift, on gait deviations. The average MINORS score for comparative studies was 19.62 out of 24 points (range 17–21), while non-comparative studies scored on average 13 out of 16 points (range 11–14).

It should be emphasized that the methodologies used in evaluating the interaction between LLD and gait are challenging. The two main methodologies reported in the literature evaluated gait asymmetry and gait deviations in subjects with either existing anatomical LLD (preferably diagnosed radiographically, not only by clinical measurements) or by acutely inducing LLD with a shoe or heel lift in subjects assumed