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Anthropometric Profile of Leg Length Inequality and its Impact on Gait

Perfil Antropométrico de la Desigualdad en la Longitud de las Piernas y su Impacto en la Marcha

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SUMMARY: Leg length inequality (LLI) affects gait – primarily pelvic and torso movements. LLI is present in around 40-70 % of the healthy population. Due to LLI's significant impact on the body, as well as the possible occurrence of a variety of associated health problems, the aim of this research is to determine whether there is a significant difference in pelvic movement in all three planes, depending on the degree of LLI. This study was conducted on a sample of 30 healthy subjects. The functional length of lower limbs was measured. When LLI was calculated, kinematic measures were taken of pelvic and lower limb movements during gait using 3D cameras and ©Vicon Motion Systems Ltd. UK. The obtained data on kinematic pelvic movement in all three planes during gait were compared with the reference values. The results show that there is no statistically significant difference in pelvic movement about the axes x, y, and z in cases of LLI of up to 18mm (p>0,05). There is a statistically highly significant positive correlation between the difference in functional leg length (r=0,575; p=0,008) and femur length (r=0,525; p=0,015) on one hand, and the difference in pelvic movement about the axis x on the other, compared to the reference values. In a healthy population with LLI from 0 to 18 mm, gait remains unaffected and an increase in LLI predominantly affects pelvic movement about the horizontal axis (x) – pelvic tilt, which exponentially increases with an increase in femur length discrepancy.

KEY WORDS: 3D gait analysis; Anthropometric measurement; Gait; Leg length inequality; Vicon system.

INTRODUCTION

Gait engages the entire locomotor system, but lower limbs have the most significant role in all its phases. Leg length inequality (LLI) affects gait – mostly pelvic and torso movement (Gurney, 2002). The clinical significance of the degree of LLI is still open to debate, so Subotnik (1981) states that a 3mm inequality is significant, while Woerman & Binder-MacLeod (1984) claims that inequality of up to 20 mm is acceptable. LLI is present in around 40-70 % of the healthy population and can reach over 20 mm – this is present in around 0.1 % of the population (Subotnick, 1981). LLI is associated with a number of health problems, such as hip osteoarthritis, loosening of the total hip prosthesis, low back pain, stress, bone fracture, and changes in walking and running economy (Chan, 2018; McWilliams *et al*., 2018; Applebaum *et al*., 2021; Alfuth *et al*., 2021).

There are two types of LLI: anatomical and functional (Gurney, 2002). Anatomical leg length inequality represents structural inequality of the lower limbs, and refers to a physical shortening of one lower limb between the femoral head and the ankle joint (outer ankle) – it represents a shortening of bone structures. It may be congenital or acquired (Subotnick, 1981). Functional inequality of lower limbs is defined as asymmetry of the lower limbs caused by muscular or joint weakness of the entire lower limb or spinal column (due to unstable foot biomechanics, adaptive shortening of soft tissues, joint contractures, ligamentous laxity, including axial curvatures, subluxations and joint rotation, including that of the spinal column (scoliosis)) (Subotnick, 1981).

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Leg length can be measured radiographically or clinically (Gurney, 2002). Radiographic measurement of leg length inequality can be performed using X-ray imaging or computed tomography (CT) (Alfuth *et al*., 2021). The abovementioned radiographic method is expensive and time-consuming, it presuppose exposure of subjects to a high degree of ionizing radiation, and result in a measurement error of around 1,6 mm, which increases with flexion deformity of the knee (Alfuth *et al*. 2021). Clinical measurement of leg length discrepancy can be performed "indirectly", by placing standing blocks under the shorter leg and monitoring pelvic SIAS alignment, or "directly", using tape measure from SIAS to the inner and outer ankle (Woerman & Binder-MacLeod, 1984; Beattie *et al*., 1990). There is disagreement about the reliability and precision of indirect and direct methods, so both can be applied. If the direct method is applied, measuring the distance between SIAS and the inner ankle (functional length) is suggested (Gurney, 2002).

LLI's biggest impact on pelvic movement is during gait, increasing movement in all three planes (about the axes x, y, z) during both dwell and gait, when movement is the greatest. The human being is a dynamic individual and, therefore, diagnosis and impact assessment of LLI should be carried out under dynamic conditions (Betsch *et al*., 2012). During gait, the line of gravity does not pass through the middle of the pelvis but is lateral and passes through the support leg. In the frontal plane (pelvic movement about the axis z) maintaining balance between body mass and muscle force (abductors) enables the small movements of abduction and adduction. In the sagittal plane (movement about the axis y), balance is maintained by gluteus maximus and thigh flexors, which enables the basic gait movements of flexion and extension. In the transverse plane (movement about the axis x), this function is performed by anterior and posterior hip rotation muscles, and balance in this plane is maintained by leaning forward (Gurney, 2002).

Gait represents a dynamic action which involves synchronized motion of muscles that can function as accelerators, decelerators, and stabilizers (Paripovic, 2015). Gait is defined as a series of coordinated movements of the torso and the limbs, performed in order to overcome a certain force and enable the body to move in space. The gait cycle can be divided into two phases: stance phase (static phase with 5 subphases) and swing phase (dynamic phase with 3 subphases) (Paripovic, 2015).

The aim of our research was to determine if there is a significant difference in pelvic movement in all three planes, about the axes x, y, and z, if leg length inequality is bigger than 10 mm in a healthy population. We used Vicon Motion Capture System, which is fast, reliable and radiation-free, and assessed the impact of anthropometric parameters of the lower limbs on gait.

MATERIAL AND METHOD

This study involved 30 subjects, 25 male (83.3 %) and 5 female (16.7 %) subjects. The subjects average age was 23.6 years. All the subjects were adults of identical height in the last 2 years, and were members of the healthy population, which means that they had not had lower-limb injuries or operations (smaller injuries, such as knocks or sprained ankles, which involve immobilization of the injured limb of up to 7 days, were tolerated). In cooperation with the Faculty of Technical Sciences of the University of Novi Sad, measurements were performed using the Vicon motion analysis system (©Vicon Motion Systems Ltd. UK). The system consisted of a base station computer with software (Nexus) for analyzing data captured by 8 separate cameras (Fig. 1) placed around the walking platform to register specific reflective spherical markers (Fig. 1) (Vicon Motion System 2020). The obtained data on kinematic pelvic movement in all three planes (about the axes x, y, and z) were compared with the reference values established by Stokes *et al*. (1989) (control group).

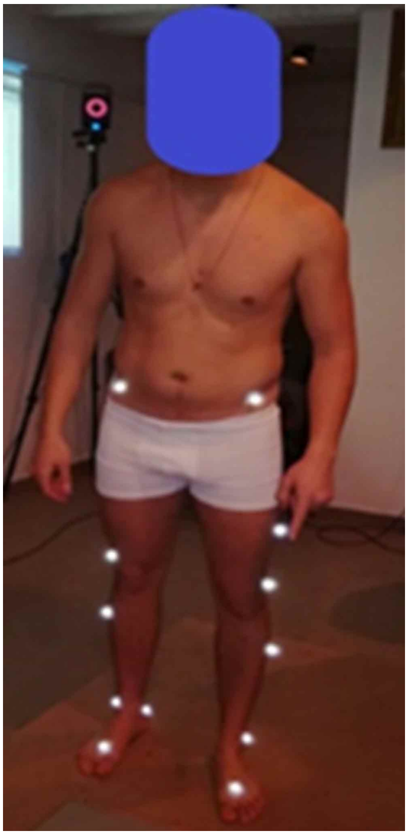

Fig. 1. The position of reflective markers on the lower limbs - with high-speed cameras around, that register 360-degree movement in space.

Motion was captured in standing position. Each subject was asked to step forward with their right leg, then the left leg, then the right leg again, and to finally resume the standing position. The subjects were divided into three groups based on leg length inequality expressed in millimeters (Fig. 2). Two separate anthropometric measurements were taken with a flexible tape measure in order to get the average value of these two measurements.

The study used descriptive statistics measures of central tendency (arithmetic mean) and measures of variability (standard deviation), as well as analytical statistics methods (t-test, Mann-Whitney, Pearson, and Spearman).

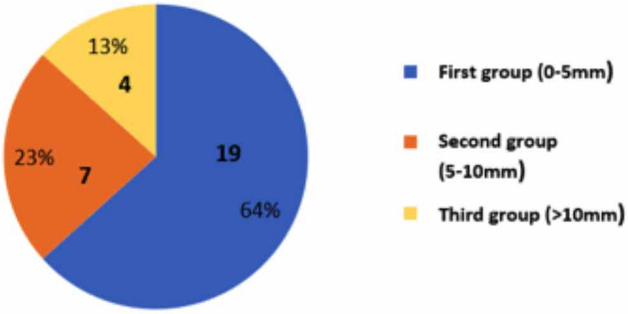

Fig. 2. Distribution of respondents by leg length inequality.

RESULTS

Anthropometric measurements. Table I shows the discrepancy between the anthropometric measures of the left and right lower limb of each subject.

Table I. Anthropometric profile of leg length inequality.

The number of subject	The anatomical leg length difference (cm)	The functional leg length difference (cm)	The thighs length difference (cm)	The shin length difference (cm)	The foot length difference (cm)	The foot width difference (cm)	The thighs circumference difference (cm)	The shin circumference difference (cm)	The knee width difference (cm)	The ankle width difference (cm)
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
1	-1,50	-0,50	0,50	-0,50	-0,50	-0,50	-0,50	-0,50	0,10	0,00
2	0,50	0,50	0,50	2,50	0,00	0,00	0,00	0,00	-0,20	-0,10
3	-0,50	-0,50	-0,50	-0,50	0,00	0,00	-1,50	-1,00	-0,20	-0,20
4	-1,50	-1,00	-0,50	-0,50	-0,50	0,00	-0,50	-0,50	-0,20	-0,20
5	0,50	1,00	0,50	0,00	-0,50	0,00	0,50	-0,50	0,00	-0,10
6	-0,30	-1,60	-0,80	-0,10	-0,20	-0,20	-0,40	-0,50	0,00	0,00
7	-0,60	0,50	-0,70	0,10	-0,50	-0,20	-0,10	-0,30	-0,10	-0,10
8	-0,50	-0,50	-0,50	-0,20	0,30	0,00	-0,30	0,40	-0,10	0,00
9	-1,10	-0,10	0,30	0,70	-0,30	-0,40	-1,10	-0,60	0,00	0,00
10	0,50	0,40	-0,50	0,10	0,60	-0,40	-1,00	-0,10	-0,10	-0,10
11	0,50	1,30	0,50	1,10	-0,30	-0,30	-0,40	-1,40	-0,10	0,00
12	-0,60	0,10	0,10	-0,60	0,10	0,20	-0,50	-0,08	-0,10	-0,10
13	0,50	1,00	0,00	0,50	-0,50	0,00	-1,00	0,00	0,30	0,00
14	-1,00	-0,50	-0,50	-0,50	-0,40	0,00	-0,50	-0,50	0,10	-0,20
15	-0,50	0,00	3,00	2,00	-0,50	-0,50	-1,00	-1,00	-0,30	-0,10
16	1,50	2,00	1,50	1,00	-0,40	0,00	0,50	-0,50	0,00	0,00
17	1,00	-0,50	0,50	-0,50	0,00	0,00	-1,00	0,50	-0,10	-0,10
18	0,40	-0,40	0,70	-1,20	-0,20	0,10	-0,50	0,20	-0,10	0,00
19	0,10	-0,20	0,20	0,10	0,20	0,20	-1,50	0,90	-0,10	0,00
20	-0,60	0,30	0,30	-,060	-0,20	-0,20	1,40	-0,20	-0,30	-0,10
21	4,90	-0,30	0,30	-0,10	0,30	-0,30	-0,50	-0,20	0,60	0,20
22	0,30	-0,40	-0,30	-0,20	-0,10	-0,10	0,80	-0,60	-0,40	-0,30
23	-0,40	-0,30	-0,20	-0,30	0,20	-0,10	1,70	-0,20	0,00	-0,20
24	0,30	0.30	0,10	0,20	-0,30	-0,20	1,90	0,20	-0,20	-0,10
25	0,00	0,10	0,10	-0,30	-0,20	-0,20	-0,50	-0,20	0,30	0,00
26	0,30	-0.30	-0,20	0,10	-0,20	-0,20	2,00	-0,40	-0,20	0,00
27	0,20	-0,20	-0,30	-0,30	0,10	-0,20	-0,30	-1,00	0,00	-0,10
28	0,80	0,20	0,50	0,30	-0,20	0,00	-0,20	-0,40	0,10	0,00
29	0,00	-0,10	-0,10	-0,20	-0,20	-0,20	-0,30	-0,20	-0,10	0,00
30	-0,40	-0,30	3,00	2,00	-0,20	-0,50	-0,60	0,70	0,10	-0,10

Pelvic kinematics. Comparison of data on kinematic pelvic movement in all three planes (about the axes x, y, and z) during gait (Fig. 3).

The results show that there is no statistically significant difference in pelvic movement about the axes x, y, and z among the subject groups (p>0.05). There is no statistically significant correlation between differences in anatomical leg length, tibia length, foot length, foot width, thigh circumference, calf circumference, knee width, and ankle width, on one hand, and differences in pelvic movement about the axes x, y, and z, on the other, compared to the reference values (p>0.05).

There is a statistically highly significant positive correlation between functional leg length inequality and differences in pelvic movement about the axis x compared to the reference values (r=0.575; p=0.008) (Fig. 4). There is a statistically significant positive correlation between femur length discrepancy and differences in pelvic movement about the axis x compared to the reference values (r=0.525; p=0.015) (Fig. 5).

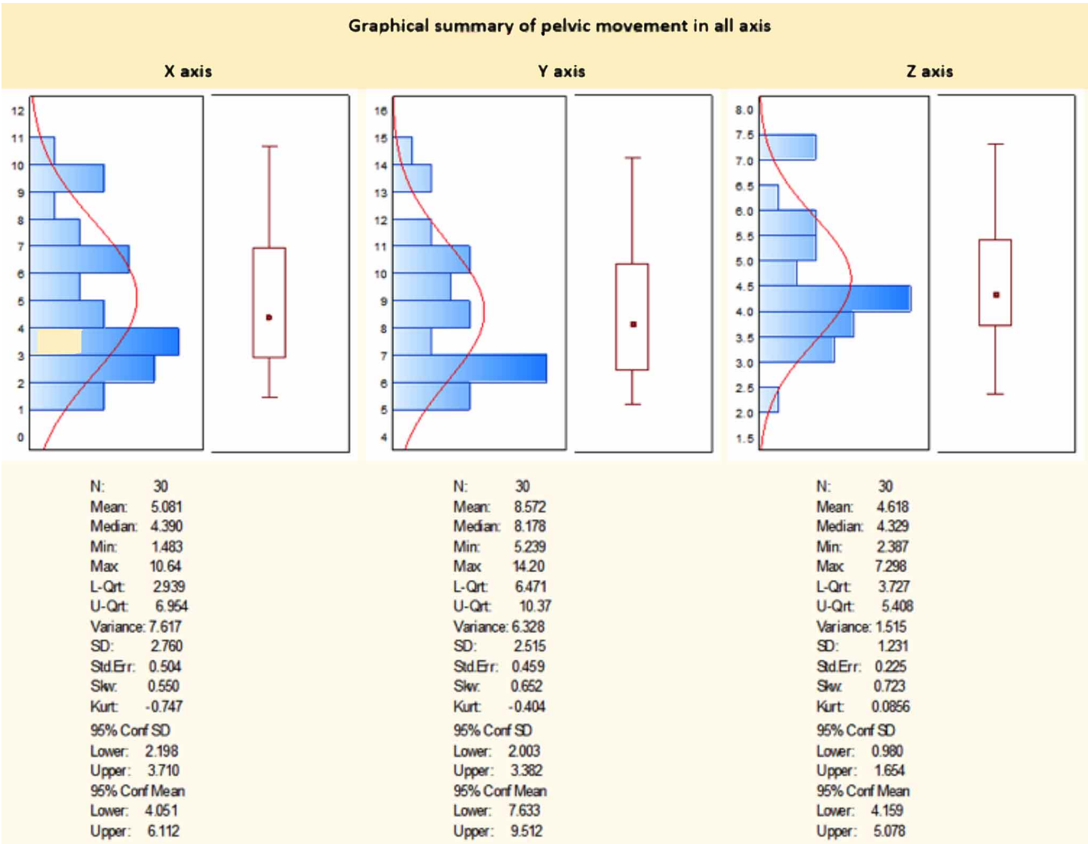

Fig. 3. Comparison of data on kinematic pelvic movement in all three planes (axes x, y, z) during gait.

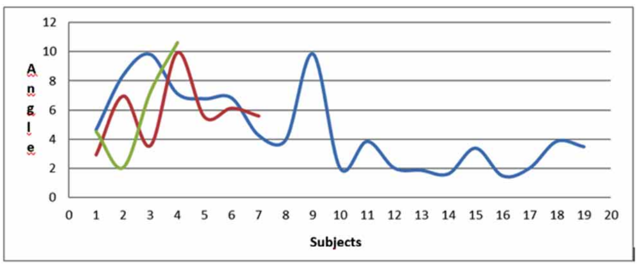

Fig. 4. Functional leg length inequality and differences in pelvic movement about the X axis in all groups.

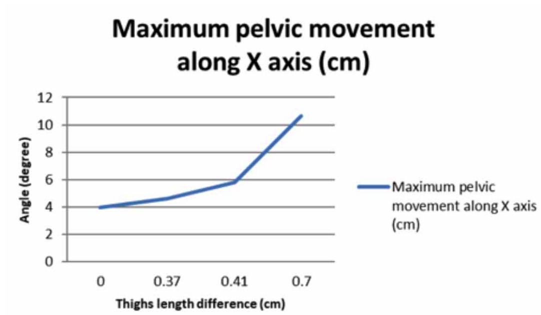

Fig. 5. Maximum pelvic movement along X axis. Femur length has the greatest impact on pelvic tilt, which increases exponentially with an increase in femur length discrepancy.

DISCUSSION

This scientific research involved anthropometric measurements of the lower limbs and 3D recording of the subjects' gait. Leg length was measured directly by two individuals, using tape measure, so that leg length was the average of the two measurements. Beattie *et al*. (1990) and Gurney (2002) concluded that the precision of dual measurement of leg length is high, the interrater reliability rises considerably (ICC 0,910), and such measurement does not necessitate radiological confirmation. We identified LLI ranging from 0 to 18mm and divided it into three categories: 0-5 mm, 5-10 mm, and >10 mm. The aim was to determine if and how much LLI affects gait, that is, pelvic and torso movement. Friend & Widmann (2008) study shows that leg length inequality of up to 1cm is present in around 70 % of the population, while our research demonstrates that the percentage is 83.3 %. Studies by Subotnick (1981) and Woerman & Binder-MacLeod (1984) shows LLI between 0.5 and 20 mm, with over 75 % presence of 10mm inequality.

LLI affects gait, resulting especially in lateral pelvic tilt, pelvis torsion, and changes of spinal posture, which is why it is suggested that movements are monitored during dynamic locomotion (gait) (Stokes *et al*., 1989; Gurney, 2002; Betsch *et al*., 2012). A study by Kaufman *et al*. (1996) confirms that gait asymmetry occurs in individuals with LLI greater than 20 mm, while the 2016 and 2017 studies by Cabral *et al*. (2016) and Khamis & Carmeli (2017) claim that gait asymmetry is present in individuals with LLI greater than 10 mm. The results of our research confirm the findings of these authors, demonstrating that gait asymmetry is present but not significant. Asymmetry increases gradually, with an increase in LLI of up to 18 mm. Like the abovementioned authors however, we did not determine the exact points at which LLI causes pathological gait. We assume that this happens when LLI is greater than 18 mm, so we intend to continue our research to test the accuracy of that assumption.

A large number of contemporary scientific papers describe the dominant impact of LLI on pelvic tilt and pelvic torsion (Young *et al*., 2000; Betsch *et al*., 2012; Alfuth *et al*., 2021). Stokes *et al*. (1989) study, published by the Karolinska Institute in Sweden, was conducted on only 8 subjects, 5 male and 3 female. It examined pelvic and thorax movement in all three planes at a normal walking speed, fast walking speed, and running speed on a treadmill (Stokes *et al*., 1989). The purpose of that study was to examine maximum pelvic movement in all three planes and compare it with maximum pelvic movement in all three planes at fast walking and running speeds. The study concluded that maximum pelvic and torso movement at a normal walking speed was within reference values, but outside reference values at fast walking and running speeds (Stokes *et al*., 1989). When we compared our results with those of Stokes *et al*. (1989) we came to a similar conclusion. Pelvic movement is within reference values at a normal walking speed irrespective of leg length inequality.

A study conducted by Betsch *et al*. (2012) in Germany involved 115 subjects and identified a statistically significant correlation between the presence of anatomical leg length inequality of up to 15 mm and minor changes in pelvic tilt, that is, pelvic movement in the sagittal plane (about the axis y). Our research confirmed the findings of Betsch *et al*. (2012) as we determined that an increase in LLI causes statistically insignificant increase in pelvic movement in all three planes (about the axes x, y, and z). Our results differ from their findings in that our research involved LLI of up to 18mm, and we identified the greatest change in pelvic movement about the axis x, while Betsch *et al*. (2012) identified it about the axis y. This can be explained by the greater sensitivity of our measurement system and by the presence of subjects with greater LLI (Gipsman *et al*., 2014). In their research, Aiona *et al*. (2015) used Vicon Motion System for kinematic and kinetic gait analysis and data analysis in children whose average age was 12.9±3.7 years, while their leg length inequality was greater than 20 mm. Their conclusion that an increase in LLI causes an increase in pelvic movement primarily about the axis x (Aiona *et al*., 2015) is consistent with our findings. The correlation between LLI and pelvic movement predominantly about the axis x was also confirmed by Young *et al*. (2000), Pitkin & Pheasant (1936), and Beaudoin *et al*. (1999). A 2000 study by Walsh *et al*. (2000) explains that the most common corrective mechanism for leg length inequality between 2 and 3cm is pelvic torsion, that is, pelvic movement in the frontal plane (about the axis z) on the longer leg, which contradicts our results. This can be explained by the fact that we monitored the dynamic position of the pelvis during gait, while Walsh *et al*. (2000) findings are predominantly based on the static position, which excludes the compensatory function of pelvic, knee, and ankle movements. Furthermore, we used a more advanced and sophisticated system for monitoring pelvic movement (Gipsman *et al*., 2014). Our research did not identify differences in gait symmetry in healthy subjects with leg length inequality of up to 15 mm. Therefore, we concluded that gait is predominantly affected by femur length, which means that an increase in femur length causes an increase in pelvic movement about the axis x in the transverse plane. In their 2018 study, Oscar Valenci *et al*., used Vicon system to analyze the impact of anthropometric measures of the lower limbs on the gait of healthy subjects. Their research is consistent with our findings as it shows that femur length has the greatest impact, irrespective of gender (Valencia *et al*., 2018). Except their study, which was considered unique in medical literature, there are no other similar studies with which to compare our findings.

To compensate for the limitations of this study, it is necessary to conduct further research on a larger number of subjects. Our research can be used to improve preparation for the operative treatment of the hip, femur, and knee, in terms of surgical approach (to avoid posterior approaches and keep exterior thigh rotators that stabilize the pelvis in the axis x) and implant selection, in order to decrease femur length inequality and enable synchronized gait.

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RESUMEN: La diferencia en la longitud de las piernas (LLI, por sus siglas en inglés) afecta la marcha, principalmente los movimientos pélvicos y del dorso. La LLI está presente en alrededor del 40-70 % de la población sana. Debido al importante impacto de LLI en el cuerpo, así como a la posible aparición de una variedad de problemas de salud asociados, el objetivo de esta investigación fue determinar si existe una diferencia significativa en el movimiento pélvico en los tres planos, dependiendo del grado de LLI. Este estudio se realizó en una muestra de 30 sujetos sanos. Se midió la longitud funcional de los miembros inferiores. Cuando se calculó el LLI, se tomaron medidas cinemáticas de los movimientos pélvicos y de los miembros inferiores durante la marcha utilizando cámaras 3D y ©Vicon Motion Systems Ltd. UK. Los datos obtenidos sobre el movimiento pélvico cinemático en los tres planos durante la marcha se compararon con los valores de referencia. Los resultados mostraron que no existe diferencia estadísticamente significativa en el movimiento pélvico sobre los ejes x, y, y z en casos de LLI de hasta 18 mm (p>0,05). Existe una correlación positiva estadísticamente muy significativa entre la diferencia en la longitud funcional de la pierna (r=0,575; p=0,008) y la longitud del fémur (r=0,525; p=0,015), y la diferencia en el movimiento pélvico sobre el eje x por otro, en comparación con los valores de referencia. En una población sana con LLI de 0 a 18 mm, la marcha no se ve afectada y un aumento en LLI afecta predominantemente el movimiento pélvico sobre el eje horizontal (x) - inclinación pélvica, que aumenta exponencialmente con un aumento en la discrepancia de longitud del fémur.

PALABRAS CLAVE: Análisis de la marcha 3D; Medida antropométrica; Marcha; desigualdad de longitud de piernas; Sistema Vicon.

REFERENCES

Aiona, M.; Patrick, K.; Emara, K.; Dorociak, R. & Pierce, R. Gait patterns in children with limb length discrepancy. *J. Pediatr. Orthop., 35(3)*:280-4, 2015.

Alfuth, M.; Fichter, P. & Knicker, A. Leg length discrepancy: A systematic review on the validity and reliability of clinical assessments and imaging diagnostics used in clinical practice. *PLoS One, 16(12)*:e0261457, 2021.

Applebaum, A.; Nessim, A. & Cho, W. Overview and spinal implications of leg length discrepancy: narrative review. *Clin. Orthop. Surg., 13(2)*:127-34, 2021.

Beattie, P.; Isaacson, K.; Riddle, D. L. & Rothstein, J. M. Validity of derived measurements of leg-length differences obtained by use of a tape measure. *Phys. Ther., 70(3)*:150-7, 1990.

Beaudoin, L.; Zabjek, K. F.; Leroux, M. A.; Coillard, C. & Rivard, C. H. Acute systematic and variable postural adaptations induced by an orthopaedic shoe lift in control subjects. *Eur. Spine J., 8(1)*:40-5, 1999.

Betsch, M.; Wild, M.; Grosse, B.; Rapp, W. & Horstmann T. The effect of simulating leg length inequality on spinal posture and pelvic position: a dynamic rasterstereographic analysis. *Eur. Spine J., 21(4)*:691-7, 2012.

Cabral, S.; Resende, R.; Clansey, A.; Deluzio, K. & Selbie, W.; Veloso A. A global gait asymmetry index. *J. Appl. Biomech., 32(2)*:171-7, 2016.

Friend, L. & Widmann, R. F. Advances in management of limb length discrepancy and lower limb deformity. *Curr. Opin. Pediatr., 20(1)*:46-51, 2008.

Gipsman, A.; Rauschert, L.; Daneshvar, M. & Knott, P. Evaluating the reproducibility of motion analysis scanning of the spine during walking. *Adv. Med. 2014*:721829, 2014.

Gurney, B. Leg length discrepancy. *Gait Posture, 15*:195-206, 2002.

Kaufman, K. R.; Miller, L. S. & Sutherland, D. H. Gait asymmetry in patients with limb length discrepancy. *J. Pediatr. Orthop., 14(1)*:49-56, 1996.

Khamis, S. & Carmeli, E. Relationship and significance of gait deviations associated with limb length discrepancy: A systemic view. *Gait Posture, 57*:115-23, 2017.

McWilliams, A. B.; Lampropoulos, A. & Stone, M. H. Revision surgery for leg length inequality after primary hip replacement. *Hip Int., 28(5)*:554-8, 2018.

Paripovic, E. *Biomehanika u Ortopediji*. Master's Thesis. Zagreb: University of Zagreb, School of Medicine, 2015. Available from: https://urn.nsk.hr/urn:nbn:hr:105:034056

Pitkin, H. & Pheasant, H. C. Sacrarthrogenetic telalgia: II. A study of sacral mobility. *J. Bone Joint Surg. Am., 18(2)*:365-74, 1936.

Stokes, V. P.; Andersson, C. & Forssberg, H. Rotational and translational movement features of the pelvis and thorax during adult human locomotion. *J. Biomech., 22(1)*:43-50, 1989.

Subotnick, S. I. Limb length discrepancies of the lower limb (the short leg syndrome). *Orthop Sports Phys. Ther., 3(1)*:11-6, 1981.

Valencia, O.; Araneda, O.; Cárcamo, M.; Carpes, F. & Guzmán-Venegas R. Relationship between lower limb anthropometry and temporo-spatial parameters in gait of young adults. *Retos, 33*:258-60, 2018.

Vicon Motion System. *Plug-in Gait Product Guide—Foundation Notes Revision 2.0, 2020*. Available from: https://www.vicon.com/downloads/documentation/plug-in-gait-product-guide

Walsh, M.; Connoly, P.; Jenkinson, A. & O'Brien T. Leg length discrepancy--an experimental study of compensatory changes in three dimensions using gait analysis. *Gait Posture, 12(2)*:156-61, 2000.

Woerman, A. & Binder-MacLeod, S. Leg length discrepancy assessment: accuracy and precision in five clinical methods of evaluation. *J. Orthop. Sports Phys. Ther., 5*:230-8, 1984.

Young, R.; Andrew, P. & Cummings, G. S. Effect of simulating leg length inequality on pelvic torsion and trunk mobility. *Gait Posture, 11*:217-23, 2000.

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