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Gait pathology presented with developmental dysplasia of the hip: a control case study
Patología de la marcha presentada con displasia del desarrollo de la cadera: un estudio de caso control

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Abstract. A well-known and long-term complication of developmental dysplasia of the hip (DDH) is improper gait pattern, early regressive joint disorder, and permanent pain. It can affect the family's psychological, social, and functional parts. This study planned to resolve foot posture and gait analysis across patients with developmental hip dysplasia and correlate it with the control group. Case-control studies determine the main results. We correlated the gait analysis results on the Zebris FDM platform. The case included candidates with DDH under conservative treatment with an abduction brace and a control group with healthy participants. This study was conducted at King Abdullah Specialized Children Hospital, Riyadh, in the Kingdom of Saudi Arabia. This research enclosed 445 outcomes with DDH and 168 for the control category. The Sign test presented a significant diversity in Zebris FDM outcomes between DDH and the control group, especially in left foot external rotation with a p-value of 0.01 (left hip mean of 4.53, n=445, SD 8.78). A significant variation was present in step width, stance phase on both legs, single support, load response, swing phase, pre-swing, and a double support p-value of 0.00 ($p<0.05$). W-sitting was preferred in 256 (n=445, 58%) of the DDH results and by 61 (n=168, 36%) from the control group. This study's outcomes presented a greater risk of pronation on the left foot and gait alteration on the right lower limb. The gait investigation presented a clear description of its patterns in paediatrics with DDH. Analyzing the gait among the DDH and the control group demonstrated a variation in each gait outcome from Zebris FDM platform software. DDH has a negative response on the gait pattern and foot posture, this is a great consequence presented in connection with Saudi applicants.
Keywords: FDM, DDH, gait, control group, Kingdom of Saudi Arabia

Resumen. Una complicación bien conocida y a largo plazo de la displasia del desarrollo de la cadera (DDH) es el patrón de marcha inadecuado, el trastorno articular regresivo temprano y el dolor permanente. Puede afectar las partes psicológica, social y funcional de la familia. Este estudio planeó resolver el análisis de la postura del pie y la marcha en pacientes con displasia del desarrollo de cadera y correlacionarlo con el grupo de control. Los estudios de casos y controles determinan los principales resultados. Correlacionamos los resultados del análisis de la marcha en la plataforma Zebris FDM. El caso incluyó candidatos con DDH bajo tratamiento conservador con aparato ortopédico de abducción y un grupo control con participantes sanos. Este estudio se realizó en el Hospital Infantil Especializado Rey Abdullah, Riad, en el Reino de Arabia Saudita. Esta investigación incluyó 445 resultados con DDH y 168 para la categoría de control. La prueba de signos presentó una diversidad significativa en los resultados de Zebris FDM entre DDH y el grupo de control, especialmente en la rotación externa del pie izquierdo con un valor de p de 0,01 (media de cadera izquierda de 4,53, n = 445, DE 8,78). Se presentó una variación significativa en el ancho del paso, la fase de apoyo en ambas piernas, el apoyo simple, la respuesta a la carga, la fase de balanceo, el rebalanceo y un valor p de doble apoyo de 0,00 ($p<0,05$). Sentarse en W fue preferido en 256 (n=445, 58%) de los resultados de DDH y por 61 (n=168, 36%) del grupo de control. Los resultados de este estudio presentaron mayor riesgo de pronación en el pie izquierdo y alteración de la marcha en el miembro inferior derecho. La investigación de la marcha presentó una descripción clara de sus patrones en pediatría con DDH. El análisis de la marcha entre el grupo DDH y el grupo de control demostró una variación en cada resultado de la marcha del software de la plataforma Zebris FDM. DDH tiene una respuesta negativa sobre el patrón de marcha y la postura de los pies, esta es una gran consecuencia que se presenta en relación con los solicitantes sauditas.
Palabras clave: FDM, DDH, marcha, grupo de control, Reino de Arabia Saudita

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Introduction

The term developmental dislocation of the hip presents a disorder that can negatively affect the child's development, depending on the diligence provided by a multidisciplinary team (Agarwal & Gupta, 2012; Klisic, 1989). Except for operative intervention and abduction splinting, there are flawed reports for all other morbidity measures and functional results, which are rarely presented (Patel, et al., 2001). This lack of insights was one of the objectives, we set up to resolve three main problems in physiotherapy proceedings, such as decreased constancy to follow-up physical therapy and other medical clinics by patients/caregivers. Impact of DDH on children's quality of life and psycho-social prosperity, and avoidance of late physiotherapy referrals. The latest update in 2022 by the American Academy of Orthopaedic Surgeons was critical. They mentioned considerable diversities in the phrasing and interpretations used in DDH description, such as what is a pathological position, and which are developmental variations. The board highlighted discrepancies in the knowledge of the DDH pathophysiology, understanding of the long-term impact, and the well-being of patients and families (The

American Academy of Orthopaedic Surgeons Board, 2022) (Jennings, Gooney, O'Beirne, & Sheahan, 2017), the need for public health screening tools, proper assessment tools, and valuable recommendation intervention plans are needed (Zamborsky, Kokavec, Harsanyi, Attia, & Danisovic, 2019). Additional research is recommended to clarify these areas (The American Academy of Orthopaedic Surgeons Board, 2022). The development of the lower limb facilitates the recognition of pathology and the timing of intervention (Bertsch, Unger, Winkelmann, & Rosenbaum, 2004). From gross motor milestones, walking is the most dynamic pattern during early age (Gimunová, et al., 2021). The investigation of hip development belongs to several specialities (Zamborsky, Kokavec, Harsanyi, Attia, & Danisovic, 2019; Klisic, 1989, p. 1). Many patients are presenting to rehabilitation services with gait pathologies for unknown reasons. After a retrospective review of medical charts, we had multiple outcomes matching the prevalence and risk factors of DDH. This area needed to be addressed and resolved to avoid any further complications.

The literature reviews presented prevalence, risk factors, diagnostic methods, and physiotherapy approaches in treatment for pediatric patients with DDH. Moreover, all published investigations focus on post-surgical gait patterns and development. No other studies explained patients' gait patterns after conservative treatment of DDH. Therefore, this study could not compare results with another, as most published investigations focus on post-surgical walking patterns and milestones. With the prevalence and outcomes of DDH, we highlighted the importance of physiotherapy, as Jennings et al. wrote in 2016, that DDH is a poorly accepted disorder as evidenced by the profusion of literature, both recent and historical (Jennings, Gooney, O'Beirne, & Sheahan, 2017).

From our results of preschool walking age, the youngest walking patient was 11 months old, and the mean was 20.09 months, higher than Dunn's 1990 finding of 18 months and Zgodas' finding of 13 months (Dunn, 1990; Zgoda, Wasilewski, Wasilewska, & Golicki, 2009). As we did not focus on milestone assessment when walking started, we could not determine the relevance, this area needed further study. The relevance of foot assessment and the effects of other deformities in the body was presented in 2010 by Oleksy et al. (Oleksy, Mika, Łukomska-Górny, & Marchewka, 2010). Another study by Kamath in 2004 states the developmental delay between DDH and the healthy group is one month (Kamath & Bennet, 2004). Zgoda et al publication, from 2009, stated that children with DDH who have not been treated start walking later than healthy children (Zgoda, Wasilewski, Wasilewska, & Golicki, 2009). This postponement was for 2–3 months and typically did not exceed the walking average age (Sharaf, 2015). Dunn's article in 1990 pointed out that 20% of children with undiagnosed and untreated DDH started walking later than 18 months (Dunn, 1990). The lower limb evolution facilitates the recognition of pathology and the timing of interference (Bertsch, Unger, Winkelmann & Rosenbaum, 2004). From gross motor milestones, walking is the most changing pattern during early age (Gimunová, et al., 2021). These studies presented strong results and supported our aim and hypothesis. The review focused on the Saudi population due to the increased prevalence of DDH, 5-6% were referred by an orthopaedic physician to physiotherapy services for fitting of abduction brace, in King Abdullah Specialized Children's Hospital (KASCH) in Riyadh (Vasilcova, et al., 2022a).

The literature review helped to develop physical therapy screening tools for the early detection of DDH and feet posture assessment. We enhanced the early detection of DDH and suggested improvements in rehabilitation access. With these results, we offered an improvement process to integrate rehabilitation care with other healthcare providers and caregivers.

We achieved the study's aim by collecting the results on the effects of DDH on gait and foot posture. We correlated the gait analysis outcomes on Zebris FDM software. The evidence included results of DDH under conservative treatment, using an abduction brace and a control group with healthy participants. DDH had a negative response to the gait pattern and foot posture. This was a great consequence presented in connection with Saudi applicants.

Materials and Methods

Participants with referrals to the Paediatric Physiotherapy Services Department were screened according to their primary diagnosis and category. Demographic information was taken. The physiotherapist assessed and intervened according to the primary diagnosis. Screening, assessment, and rehabilitation programs are devised in collaboration with the child, and their caregivers. Gait analysis was assessed for patients who can walk at least ten steps independently, without any assistive device. We used the Zebris force distribution measurement (Zebris FDM) platform.

This study aimed to determine the effect of DDH on the gait. With the following hypothesis:

H 1 We assume that the hip's developmental dysplasia affects gait in children from 11 to 60 months.

H 2 Children with DDH of a higher frequency sit in the W-sit.

H 3 We assume that there is a gait difference between a healthy patient and a patient with DDH.

Case-control studies determine the main results. We correlated the gait analysis results on Zebris FDM. The case included candidates with DDH under conservative treatment with an abduction brace and a control group with healthy participants.

According to the STROBE checklist (STROBE, 2023;

Vandenbroucke, et al., 2007), the methodology was divided into sub-categories. This study was conducted at KASCH, Riyadh, in the Kingdom of Saudi Arabia (KSA). Retrospectively we assessed paediatric participants aged 11-60 months. Within this age, the child learns to walk, starting with weight bearing on lower limbs and feet,

The results on the Zebris FDM were collected from 2020 until 2022. To enter the data quickly, we created a flow chart. Every parent signed the informed consent form before the measurement. None of the parents recoil consent from the study. No mischief or trauma was noted during the Zebris FDM analysis.

If any developmental delay or other complication occurred in any group, the primary (referring) physician was contacted. The principal investigator and the co-investigator screened all candidates.

Study design

Candidates were referred to the Paediatric Physiotherapy Services Department in KASCH from the orthopaedic clinic from 2016 to 2022 with the conservative treatment of DDH. The whole process of the DDH project is described in the flow diagram (Figure 1). For case control, we compared the gait analysis results with those of the Zebris FDM. The blind matching between the groups was performed.

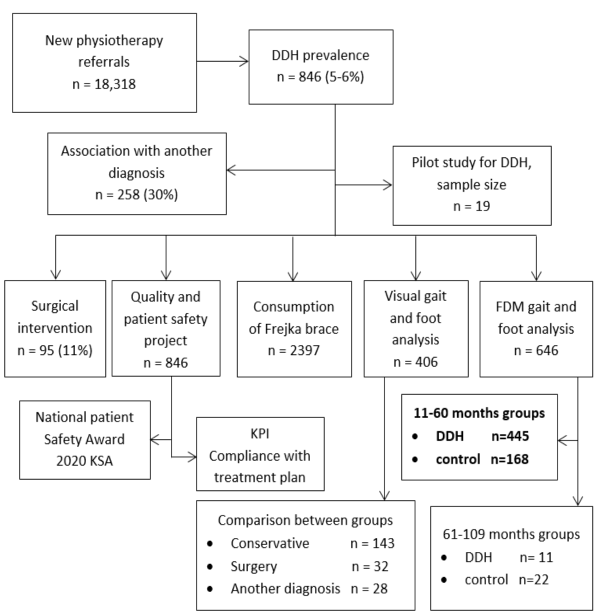

Figure 1. DDH Project flow diagram

Sample size - Participants

This study aimed to define the effect of DDH on gait pathology, feet, and heel pronation. This study on conservative treatment of DDH is exclusive, and no other publications targeted gait and foot position. The age group was defined as the youngest participant, who could walk for ten steps, and was eleven months old. The highest age is determined according to the preschool age. The pilot study determines the sample size for each hypothesis (Table 1) (Vasilcova, et al., 2022b). We used an open-source calculator, SS, to define the sample size for the cohort study. The total sample size is 1110, Table 1, for the exposed in our study DDH diagnosis and non-exposed, healthy control group combined. Five hundred fifty-five results for each group (Table 1). The total number of participants was expected to reach 600.

Table 1.
Sample Size

Sample Size: X-sectional, Cohort, & Randomized Clinical Trials			
Two-sided significance level(1-alpha):			95
Power (1-beta, % chance of detecting):			79
The Ratio of sample size, Unexposed/Exposed:			1
Percent of Unexposed with Outcome:			5
Percent of Exposed with Outcome:			9.5
Odds Ratio:			2
Risk/Prevalence Ratio:			1.9
Risk/Prevalence difference:			4.5
	Kelsey	Fleiss	Fleiss with CC
Sample Size - Exposed	513	511	555
Sample Size-Non exposed	513	511	555
Total sample size:	1026	1022	1110

- Results from OpenEpi, Version 3, open-source calculator—SSCohort.

Sampling technique

Analysis of the conservative DDH group

Demographic information was collected and entered into the working sheet. According to the study description, we applied inclusion and exclusion criteria to clear data. Parents were contacted to participate in this study and bring their children for assessment. Candidates aged 11-60 months.

Inclusion Criteria

- Referred to the Physiotherapy Services by the Orthopaedic Clinic with a diagnosis of DDH.
- Participant under DDH conservative treatment.
- Participants walk at least ten steps independently.

Exclusion Criteria

- Paediatrics with genetic, neurologic disorders, or post lower limb surgery.
- Any participant above 61 months.

Analysis of the control group

Control group patients were referred to the Paediatric Physiotherapy Services Department in KASCH from the general paediatric clinic. An appointment booking was made after the screening. Participants from the control group were discharged after gait analysis. Ability to walk for at least ten steps independently. Candidates aged 11-60 months.

Inclusion Criteria

- Referred to the Physiotherapy Department from another Paediatric Clinic in KASCH.
- Participants only for gait analysis.

Exclusion Criteria:

- Paediatrics with orthopaedic, genetic, neurologic disorders or post lower limb surgery.
- Any participant above 61 months of age.

Measures

Every parent was instructed before measurement. To avoid any scary or traumatic event for candidates, they were allowed to touch and walk on the platform with their parents before analysis. The span of the analysis was approximately 20-30 minutes.

Parents and toys helped the child to be comfortable and walk over the platform. Every assessment was carried out barefoot, and the platform was disinfected after each analysis.

Patients were assessed by physiotherapists: principal investigator or co-investigator. The participant was assessed barefoot and walked across the Zebris FDM independently for at least ten steps for gait analysis.

Design and Procedures

The Zebris FDM analysis was performed in the gait laboratory in KASCH. The platform was arranged in the laboratory area with two meters of free area around it. Origin and final points were marked, to control the same dimensions for each attendant. Gait parameters at Zebris FDM characterized individual gait phases (Zebris Medical GmbH, 2015; Zebris Medical GmbH,2016).

All data were stored in the study records, and random follow-ups prevented missing demographic information or other data.

Bias

There were no causes of bias. Multiple physiotherapists treated patients with DDH. They had an experience of more than two years, and PI provided serial education sessions.

Statistical Analysis and Data Management

To avoid any data reproduction and collection, we utilized the Medical Reference Number (MRN) in a separate coding sheet, with entry by the PI only. PI changed the MRN and used only added numbers in the statistical sheet.

All data were processed with Microsoft Word, Microsoft Excel, and Statistica 14 EN – TIBCO® Data Science Workbench, Version 14.0.0.15 (version 2023).

Data were established as "missing completely at random" (MCAR), they were directed as multiple imputations. Some Zebris FDM results were not issued or recorded as zero from the software. Those were not used and were properly discarded.

All data from DDH and the control group went through the normality test Kolmogorov-Smirnov test, the Shapiro-Wilk test, and the Anderson-Darling test, with a P-value greater than 0.05. All results were described using descriptive statistics as a total number, mean, descriptive statistics and standard deviation. The Sign test compared the results of DDH and the control group to determine a difference in the Zebris FDM gait results, tests were significant at $p<0.05$. The zero and alternative hypotheses tested the colourant coefficient level in statistical processing. For statistical the statistical process and data analysis were consulted with a biostatistician.

Ethical consideration

Ethical approval was collected from the Masaryk University Research Ethics Committee with number EKV-2021-018, and King Abdullah International Medical Research Centre in Riyadh, KSA with study number SP21R/364/06. There was NO sponsor or grant for this study.

Results

Demographic Information

We gathered 456 results for DDH and 190 for the control group. The youngest participant was eleven months old, and the oldest was 104 months in the DDH group and 109 months in the control group. Excluding criteria determine the oldest participant to be 60 months due to preschool age. We included ages from 11 to 60 months (Table 2) and the DDH group contained 445 (n=456, 98%, Table 2) results. 104 (n=445, 23%, Table 2) being male, and 341 (n=445, 77%, Table 2) were female. Right DDH presented in 185 (n=445, 42%, Table 2), left in 222 (n=445, 50%, Table 2), and bilateral in 38 (n=445, 8%) results. Left AVN was diagnosed in only one (n=445, 0.5%) participant under conservative treatment. Left Coxa Valga presented in three (n=445, 0.5%) candidates, and Coxa Vara was undiagnosed. W-sitting was preferred in 256 (n=445, 58%) of the DDH results.

Table 2.
Demographic information - DDH, and control group

Demographic information		Age group 11-60 m *	
		DDH	Control
All	n=	445 (98%)	168 (88%)
Gender	Male	104 (23%)	76 (45%)
	Female	341 (77%)	92 (55%)
DDH	Rt	185 (42%)	0
	Lt	222 (50%)	0
	Bilateral	38 (8%)	0
AVN	Lt	1 (0.5%)	0
Coxa Valga	Lt	3 (0.5%)	0
Coxa Vara		0	0
W-sitting	Yes	256 (58%)	61 (36%)

*All results are described as the total number of results and %.

The control group measurements were n=168 (n=190, Table 2), aged from 13 until 60 months (n=168, 88%), presented 76 (n=168, 45%) males and 92 (n=168, 55%) females. DDH, AVN, Coxa Valga, and Vara were not presented in this group. W-sitting was preferred by 61 (n=168, 36%, Table 2) participants.

The variation between DDH and the control group, started by showing contrast in demographic data (Table 3). The statistical results in Table 3 showed a great variability between these two groups. DDH participants favoured w-sitting more often than the healthy group. These outcomes justify our hypothesis: H 2 Children with DDH of a higher frequency sit in the W-sitting (Table 3).

Table 3.
Sign Test: Comparison of demographic results - DDH vs. Control group

Demographic information	Sign Test*			
DDH vs. Control group	No.	% v<V	Z	p-value
W-sitting	32	100.00	5.48	0.00

*All results are described as a total number, mean, and descriptive statistics results. Marked tests are significant at $p<0.05$.

FDM platform - DDH vs Control group

Gait parameters at Zebris FDM characterize each phase of the gait (Table 4, Table 5, Table 6). The analysis started with geometry, including parameters such as foot rotation, step length, stride length, step width, and the step phases in the stance and swing phases. Time-dependent gait parameters presented step and stride time, cadence, and the average speed of the interval are analyzed. Foot rotation was the angle between the longitudinal axis of the foot and the movement direction. A negative value represented inward rotation, not in our groups. An outward rotation had a positive value presented with the DDH group. The sign test disclosed a significant difference. Step width, in cm for the DDH, described the right and left foot distance, higher in the DDH group. The Sign test result established a significant difference between these two groups (Table 4). The stance phase, in %, explained the stage of a gait cycle in which the foot had contact with the ground, and it revealed a shortening of DDH's left lower limb. The Sign test in Table 4 revealed a significant difference between these two groups, for both limbs. The loading response phase, in %, unveiled the initial ground contact and contralateral toe-off phase. The Sign test presented a p-value of 0.00 ($p<0.05$, Table 4) for the right and left limbs 0.16, which indicated a significant difference between these two groups on the right lower limb. Mid-stance phase shown in %, was the contralateral toe-off stage, and the body's center of gravity transferred over the weight-bearing foot more in the DDH group. The Sign test illustrated a p-value of 0.00 ($p<0.05$) for both limbs, a significant difference (Table 4). Pre-swing phase, in %, is described as the stage during a gait cycle that begins at contralateral initial contact (when the heel of the contralateral side touches the ground) and ends at the toe-off of the viewed side of the body. The Sign test presented a significant difference (Table 4). The swing phase, in %, was the stage when the foot had no contact with the ground. It can be presented during limping gait or in the DDH group with participants who were avoiding weight bearing on the left leg. Total double support, in %, was the sum of the loading response and pre-swing phases. The Sign test result presented a significant difference between these two groups (Table 4).

Table 4.
Sign Test: FDM parameters - DDH vs. Control group

Gait parameters	Sign Test*				
11-60 m DDH vs. Control group	Side	No.	% v<V	Z	p-value
Step length, cm	Right	167	45.50	1.08	0.27
	Left	166	49.39	0.07	0.93
Foot rotation, degree	Right	169	53.84	0.923	0.35
	Left	168	59.52	2.39	0.01
The step time, sec	Right	167	49.70	0.00	1.00
	Left	167	52.69	0.61	0.53
Stance phase, %	Right	169	60.35	2.61	0.00
	Left	168	63.69	3.47	0.00
Load response, %	Right	137	64.96	3.41	0.00
	Left	148	56.08	1.39	0.16
Single support, %	Right	137	37.22	2.90	0.00
	Left	148	41.89	1.89	0.05
Pre-swing, %	Right	169	59.76	2.46	0.01
	Left	168	61.30	2.85	0.00
Swing phase, %	Right	169	39.64	2.61	0.00
	Left	168	36.30	3.47	0.00
Toe off, %	Right	160	60.62	2.60	0.00
	Left	164	64.02	3.51	0.00
Total double support, %		168	63.09	3.312	0.00
Stride length, cm		168	48.21	0.38	0.69
Stride time, sec		168	51.19	0.23	0.81
Step width, cm		169	58.57	2.15	0.03
Cadence, steps/min		169	50.29	0.00	1.00
Velocity, km/h		169	42.60	1.84	0.06
Variability of velocity, %		159	51.57	0.31	0.75

*All results are described as a total number, mean, and descriptive statistics. Marked tests are significant at $p<0.05$.

The butterfly diagram of Zebris FDM analysis illustrates the result in Table 5. The "Length of the gait line" clarified the position of the centre of pressure (COP). The Sign test in Table 5 did not show statistical significance in these results. The “single support line” was an element of the mid-stance phase. The Sign test result presented a significant difference between these two groups. The anterior/posterior position presented the shift of the COP forward or backward. The Sign test result showed a p-value of 0.01 ($p<0.05$), a significant difference between the two groups on the right lower limb.

Table 5.
Sign Test: Butterfly parameters: DDH vs. Control group

Butterfly parameters	Sign Test*				
11-60 m DDH vs. Control group	Side	No.	% v<V	Z	p-value
Gait line length	Right	169	49.11	0.15	0.87
	Left	167	50.29	-0.00	1.00
Single support line	Right	168	35.11	3.78	0.00
	Left	168	41.07	2.23	0.02
Ant/post position		168	60.11	2.54	0.01
Ant/post variability		159	51.57	0.31	0.75
Lateral symmetry		166	54.21	1.00	0.31

*All results are described as a total number, mean, and descriptive statistics. Marked tests are significant at $p<0.05$.

The maximum pressure diagrams declare the averaged and normalized pressure curves. These results were divided into the right and left lower limbs (Table 6 and Table 7). The Sign test result showed a significant difference.

Table 6.
Sign Test: DDH vs. Control group, right limb

Gait line, Right limb	Sign Test*			
11-60 m DDH vs. control group	No.	% v<V	Z	p-value
Max force 1 N	148	64.86	3.53	0.00
Max force 1 time %	142	50.00	-0.08	0.93
Max force 2 N	128	54.68	0.97	0.33
Max force 2 time %	119	51.26	0.18	0.85

*All results are described as a total number of mean and descriptive statistics results. Marked tests are significant at $p<0.05$.

Table 7.
Sign Test Gait line: DDH vs. Control group, left limb, 11-60 months

Gait line, Left limb	Sign Test*			
11-60 m DDH vs. Control group	No.	% v<V	Z	p-value
Max force 1 N	146	63.69	3.22	0.00
Max force 1 time %	145	48.96	0.16	0.86
Max force 2 N	131	58.01	1.74	0.08
Max force 2 time %	124	49.19	0.08	0.92

*All results are described as a total number of mean and descriptive statistics. Marked tests are significant at $p<0.05$.

H 1 We assume that the hip's developmental dysplasia affects gait in children from 11 to 60 months.

- Approved.

Sign test (p-value is $p<0.05$) and statistical test presented and compared results of DDH and control group results. The Sign test demonstrated diversity in foot rotation, stance phase, load response and single support, pre-swing, swing phase, double support, and step width. These results established our hypothesis: Table 3, 4, 5, 6, 7.

H 2 Children with DDH of a higher frequency sit in the W-sit.

- Approved.

The statistical results showed a difference between the groups. Children with DDH under conservative treatment sat in w-sitting more often than the control (healthy) group. These results support our hypothesis: Tables 2 and 3.

H 3 We assume that there is a gait difference between a healthy patient and a patient with DDH.

- Approved.

Tables 4, 5, 6, and 7, presented significant results, the p-value is $p<0.05$. The Sign test showed a difference in left foot rotation, stance phase on limbs, right load response and single support, pre-swing, swing phase for limbs, double support, and step width. Results from p Tables 4, 5, 6, and 7 supported our hypothesis.

Discussion

Physiotherapists treat short and long-term cases that affect physical development, activity, and ability to play, learn, and socialize (American Physical Therapy Association, 2021). The effectiveness of screening is highly dependent on the therapist's skill. Clinicians should be adequately trained, with opportunities for skills reassessment (Patel & et al., 2001). To reach a success rate of 90% or more, it is essential to start screening, diagnostics and conservative treatment of DDH as soon as possible, not only at rehabilitation services but at speciality and nursing clinics. Within Saudi Arabia, there is a comprehensive DDH presentation for newborns to six years of age, making treatment decisions difficult and outcomes unpredictable (Sadat-Ali, 2020).

The DDH prevalence in Saudi Arabia varies in cities, hospitals, and centres. This spectrum is from 3.8 to 36.5 cases per 1000, according to last studies (Vasilcova, et al., 2022a; Alosaimi, et al, 2020; Sadat-Ali, 2020; Mirdad, 2002). Prevalence in the Paediatric Physiotherapy Services Department in KASCH, Riyadh, KSA was 5-6% over 1000, per capita, presenting 46.18 cases per 1000 (Vasilcova, et al., 2022a). It is high according to other studies. DDH is not always present after delivery, but some neonatal screenings present hip instability as high as 1 in 100 newborns (Zamborsky, Kokavec, Harsanyi, Attia & Danisovic, 2019). These numbers are increasing and DDH awareness needs to improve.

We evaluated the difference between the conservative treatment of DDH and the healthy control group. Our results showed the importance of treating hip complications such as DDH, which affects gait and foot posture. DDH increased the pathology on the hip due to the body weight shifting. The latest survey from 2023 by Aslam et al. mentions decreased hip angle, increased internal rotation and upward pelvic tilt (Aslam, et al., 2023). The most common reason for foot and gait problems is increased weight from being overweight or obese and from decreased activity (Oleksy, Mika, Łukomska-Górny, & Marchewka, 2010).

Our study's results correlate with a 2021 publication description of gait patterns for DDH patients done by Lee et al. (Lee, et al., 2021). Heel-strike development increased the swift in-the-ground reaction force (GRF) with foot contact when the velocity decreased to zero. By comparing the pressure at which the foot (endpoint) and the limb press onto the floor, we can manage the GRF. The incorrect swing phase is increasing the loading of GRF (Lee, et al., 2021). Toddlers and preschoolers are growing and learning gross motor skills. Therefore, with any pathology, they are proven to compensate for their movement (Lee, et al., 2021). DDH is a problem in the hip joint, affecting gait patterns.

Zebris FDM software results presented a clear picture of the gait with DDH. The correlation of the outcomes between the DDH and the control group demonstrates diversity in every gait phase. We could characterize the movement pattern of DDH according to the results: the left foot was in an out-toeing position, which is increasing burden on the medial ankle side, and longitudinal arch area. This weight placement may explain foot pronation, approved by the butterfly parameters. The left reduced ankle alters the weight and centre of gravity into the right side, increasing the load response on the right lower limb. It might be visible as limping or with w-sitting, which was statistically approved. In 2014, Larnert et al. highlighted an association between DDH and pelvic obliquity, windswept deformity, and scoliosis (Larnert, Risto, Hagglund, & Wagner, 2014).

DDH perception needs promotion, and it is essential to start with public education at the clinic and through social media (De Pellegrin, Damia, Marcucci & Moharamzadeh, 2021; Para, Batko, Ippolito, Hanna & Edobor-Osula, 2021). The newest publications, research, and projects are opening doors to many new ideas in preventing possible complications for all paediatric patients with DDH or a high risk of DDH.

As with any analysis study, this study had limitations. The main limitation was that multiple therapists analysed gait and foot posture and missing information in patient documentation. This study started during the COVID-19 pandemic. The follow-up booking for patients was limited to acute patients, and many booked appointments were cancelled. A therapist with different experience levels needed help analysing gait and foot pathologies during the COVID-19 pandemic problem due to limited therapists at the Paediatric Physiotherapy Services Department.

Conclusion

This study opened up the chance to improve physiotherapy assessment and analysis for patients with DDH. A physiotherapist is fundamental in the treatment of DDH. Targeted research will improve the approach and view of this topic. Further studies should include all participants with DDH who are diagnosed with other diagnoses after surgery and referred to orthopaedic and other clinics. The focus should be creating a gait screening tool for all patients at the Paediatric Physiotherapy Services Department to prevent pathology and ease the discharge process.

The conclusion of this study of Zebris FDM software results presented a clear view of gait patterns in participants with DDH. The comparison between the DDH and the control group presented a diversity in every gait phase.

DDH has a negative response on the gait pattern and foot posture, this was a great consequence presented in connection with Saudi applicants.

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Conflicts of Interest

The authors declared no potential conflicts of interest for the research, authorship, and/or publication of this article.

Ethical Approval

The study was conducted following the Declaration of Helsinki, and approved by the Institutional Review Board from King Abdullah International Medical Research Center, Riyadh, Saudi Arabia with memo Ref. No. IRBC/1747/21, study No. SP21R/364/06 on the 23rd of August 2021 and by The Masaryk University Research Ethics Committee, Brno, Czech Republic Ref. No. EKV-2021-018, proposal No. 0107/2021 on 31st of May 2021.

Consent for publication

All authors have read and agreed to the published version of the manuscript.

Data Availability Statement

Data are stored by the Principal Investigator.

Informed Consent Statement

Parents agreed to participate in this research and signed the informed consent before the session. No parent withdrew consent from the study, and no harm or injury was noted during the assessment.

Author Contributions

V.V.: principal investigator, conceptualization, data curation, formal analysis, investigation, methodology, project administration, resources, software, validation, visualization, writing—original draft, writing—review, and editing.

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