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Prevalence of W-sitting in preschool and school age, with gait and foot analysis

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ABSTRACT
Purpose. This study aimed to investigate the prevalence of W-sitting, gait, and foot analysis in preschool and school-age participants.
Methods. A cohort study was conducted, including healthy participants without any pathology or other diagnoses. Foot disposition was determined using the Foot Posture Index (FPI-6), and gait patterns were analysed using the Zebris FDM platform. The study was conducted at the Gait Laboratory of King Abdullah Specialised Children's Hospital and Prince Sultan University in Riyadh, Saudi Arabia. A total of 190 participants were included, ranging in age from 12 to 109 months. The preschool-aged children (12–60 months) comprised 168 participants (88%), while the school-aged children (61–109 months) comprised 22 participants (12%).
Results. The preschool group had a female majority (92, 55%), while males accounted for 76 participants (45%). W-sitting was observed in both groups, with 61 preschool participants (36%) and eight school-aged participants (36%) preferring this posture. Gait analysis revealed patterns specific to preschool children aged 12–60 months, indicating an increased pronation on the left foot. However, the overall risk of developing foot pronation or supination deformities in Saudi participants was low, though not negligible.
Conclusions. W-sitting may impact foot posture and gait patterns. Early assessment of foot posture and gait during the paediatric age is recommended to minimise the risk of complications or deformities that may affect a child's development.
Key words: W-sitting, FPI-6, Zebris FDM, school age, KSA, preschool

Introduction

The recent scientific literature compiles the latest updates on the prevalence of risk factors, diagnostic methods, and physical therapy approaches for treating paediatric patients with foot and gait pathology. However, previous studies have not explained gait patterns in preschool patients. Published research focuses on gait and the development of specific diagnoses or pathologies rather than on healthy participants. Early and appropriate referral to physical therapy is essential to avoid delays in patient care [1].

According to Jordan et al. [2], primary care research on musculoskeletal problems in children identified foot pathologies as the most common. Similarly, a study by Bertsch et al. [3] documented the evolution of paediatric foot shape and loading forces during standing and walking. Flexible flatfoot in early childhood is a frequently diagnosed condition, as evidenced by clinical investigations, and in most cases, it is age-appropriate and asymptomatic, requiring no treatment [4]. However, in some cases, the underlying causes may be neuropathic or linked to anatomical pathologies of the ankle [5]. Gould et al. [6] reported the development of the medial longitudinal arch in children aged 11 months to 5 years, noting a prevalence of hyper-pronation in 77.9% of cases.

Previous studies have analysed children's foot posture using plantar footprint assessments, identifying problematic flatfoot conditions when the plantar foot-

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print area increases significantly [7]. Children develop a different medial longitudinal arch during early childhood than adults [8, 9]. The foot posture should be evaluated during developmental milestones along with the possible presence of other conditions, such as hypotonia or hypermobility [7, 9, 10]. Moreover, Sutherland [11] emphasised the importance of understanding the natural progression of immature gait patterns to correctly interpret pathological ones, highlighting the predominant use of the hip flexors and extensors over plantar flexion of the ankle during early development. Plantar pressure, which reflects the force exerted by the foot on the ground and its distribution, plays a critical role in gait analysis [12]. Paediatric peak vertical forces during overground reactions can reach up to 120% of body weight [4].

Understanding the development of the lower limb is essential for recognising pathology and determining the appropriate timing for intervention [3]. Among gross motor milestones, walking is the most dynamic and evolving pattern during early childhood [13]. There is a pressing need for public health screening tools, accurate assessment methods, and comprehensive intervention plans [14]. Furthermore, additional research is necessary to clarify these areas [15]. Developing the lower limb is instrumental in identifying pathologies and determining the right time for intervention [3]. Among gross motor milestones, walking remains the most significantly evolving pattern in early childhood [13]. The study of hip and foot development is interdisciplinary and spans multiple specialities [14, 16]. Numerous patients with gait abnormalities at rehabilitation services are often affected for unknown reasons. Addressing this knowledge gap is critical in avoiding further complications.

The importance of foot assessment and the impact of other body deformities has been highlighted by Oleksy et al. [9]. The development of the lower limb aids in recognising pathologies and the timing of intervention [3]. Walking is the most dynamic pattern observed in the early stages of gross motor development [13]. These findings support the objective and hypothesis of our study. In this sense, physical therapists (PTs) play a crucial role in helping individuals preserve, recover, and enhance their movement, activity, and functionality, thereby promoting optimal performance, health, and overall quality of life [17, 18]. Their services are vital in preventing, minimising, or eliminating impairments in body functions and structures, as well as activity limitations and participation restrictions [17, 18].

In today's healthcare environment, physical therapists are recognised as fundamental providers of rehabilitation, performance enhancement, prevention, and risk reduction. They play a pivotal role in establishing standards for physical therapy practice and shaping healthcare policies to ensure the accessibility, availability, and optimal delivery of physiotherapy services [18–20].

In this context, collecting data on gait and foot posture is essential. Therefore, this study aimed to determine the prevalence of W-sitting, gait patterns, and foot abnormalities in preschool and school-aged children. The study was guided by the hypotheses that preschool children are at a higher risk of foot pronation than school-aged children, that preschool-aged children tend to prefer sitting in the W-sitting position, and that there is a difference in gait patterns between the right and left lower limbs in preschool-aged children.

Material and methods

The study aimed to analyse the gait and foot position of preschool and school-age participants. The primary purpose was to determine the prevalence of W-sitting in preschool and school-age Saudi participants.

Hypotheses

Hypothesis 1: It is assumed that preschool children are at a higher risk of foot pronation than school-age children.

Hypothesis 2: It is assumed that preschool children prefer to sit in the W-sitting posture.

Hypothesis 3: It is assumed that there is a gait difference between the right and left lower limbs in preschool children.

Study design

A prospective cross-sectional cohort study was conducted. Participants were assessed in the gait laboratory at King Abdullah Specialised Children's Hospital (KASCH) and were referred from other paediatric clinics between 2020 and 2023. The study was conducted in accordance with the STROBE guidelines and the principles outlined in the Declaration of Helsinki [21, 22].

Participants

The study included 190 healthy participants, with ages ranging from 12 to 109 months. Inclusion and exclusion criteria were applied to ensure that only healthy participants were included in the study, excluding those with any known pathology or diagnosis. Participants were referred from the general paediatric clinic for gait and foot analysis.

Inclusion criteria: Participants with a physiotherapy referral for gait and foot analysis. All were screened in the King Abdullah Specialised Children's Hospital (KASCH) gait laboratory. Only participants who could walk at least ten steps independently, without the use of any assistive device, were included in the gait analysis.

Exclusion criteria: Not able to walk independently for at least ten steps. Paediatric participants with genetic or neurological disorders or post-lower limb surgery were excluded from this study, as were participants older than 120 months.

The study adhered to ethical guidelines, and informed consent was obtained from the legal guardians of all participants before data collection. The data were stored securely, and no participants withdrew from the study. No trauma was noted during the analysis. The study was conducted from 2020 to 2023 at KASCH in Riyadh, Kingdom of Saudi Arabia.

Study size

The study included children aged 12 to 109 months, with the preschool group defined as those aged 12 to 60 months and the school-age group as those aged 61 months and older. Sample size calculations were performed using the OpenEpi open-source calculator (Table 1), which indicated a required sample size of 52 participants, divided into two groups. The total number of participants was expected to reach 60, taking into consideration a potential drop-out or incomplete data.

Variables

The Foot Posture Index Six (FPI-6) evaluates the foot as a multi-segmental complex in double-leg support, characterising pronation with a + (plus) and supination with a – (minus) sign. Scoring is 2 (two) points in all six factors, divided into rearfoot and forefoot assessment in the transverse, frontal/transverse, frontal, and sagittal planes. Scoring within normal limits is from 0 to +5, pronation is from +6 to +9, and high pronation is when results are more than +10. Supination is from –1 until –4, and high supination is from –5 to –12 [7, 23, 24].

Before the measurement on the Zebris FDM [25, 26], parents were instructed about the process. To ensure participants felt comfortable and avoided any discomfort or traumatic experiences, they were allowed to touch and walk on the Zebris FDM platform with their parents before the actual analysis. The analysis took approximately 20 to 30 min, during which the parents and toys helped the child stay at ease and walk independently on the platform, which was disinfected after each use. Participants were assessed barefoot, walking across the platform for at least ten independent steps. Physiotherapists, including the principal investigator and a co-investigator, conducted the assessments. The Zebris FDM, manufactured by Zebris Medical GmbH, Germany, and the Zebris FDM 1.5, with software v1.12, underwent analysis in the gait laboratory at KASCH. The platform was set up with a two-metre empty surrounding area. Starting and ending points were marked to ensure accurate dimensions for each participant's walk. Individual gait phases were analysed for every participant on the Zebris FDM platform [25, 26].

Table 1. Sample size calculation for cohort study on W-sitting, gait patterns, and foot posture*

Sample size description			Calculation results
Two-sided significance level (1-alpha)			95
Power (1-beta, % chance of detecting)			80
Ratio of sample size, unexposed/exposed			1
Percent of unexposed with outcome			5
Percent of exposed with outcome			41
Odds ratio			13
Risk/prevalence ratio			8.2
Risk/prevalence difference			36
	Kelsey	Fleiss	Fleiss with CC
Sample size – exposed	22	21	26
Sample size – non-exposed	22	21	26
Total sample size	44	42	52

Fleiss with CC – fleiss with continuity correction
* results from OpenEpi, version 3, open-source calculator – SSCohort module

Bias

Potential sources of bias were carefully considered and mitigated throughout the study. Participants were recruited from multiple paediatric clinics to minimise selection bias and ensure a diverse sample. Although all participants were referred, the sample may not fully represent the general paediatric population. Measurement bias was addressed using the Zebris FDM platform, a standardised and validated tool for gait and foot analysis, and ensuring that assessments were conducted under uniform conditions. Twelve therapists with over five years of experience performed the assessments independently to reduce evaluator bias. With over 18 years of experience, the principal investigator provided at least five training sessions to ensure standardised procedures and minimise variability across the evaluators. Despite these measures, residual bias cannot be excluded entirely, mainly due to the reliance on a specific population and equipment setup, which causes some results to take negative values. Recognising these limitations enhances the transparency and reliability of the findings.

Statistical analyses

To prevent data duplication, the Medical Reference Number (MRN) was stored in a separate coding sheet accessible only to the Principal Investigator (PI). The MRN was replaced with unique numerical identifiers in the statistical dataset to ensure confidentiality. All data were processed using Microsoft Word, Microsoft Excel (Microsoft Corporation, Redmond, WA, USA), and Statistica 14 EN [TIBCO® Data Science Workbench, Version 14.0.0.15 (2023)]. Before the statistical analysis, we set up our data as missing completely at random (MCAR). We dealt with data through multiple imputations. Some Zebris FDM results were not distributed or were marked as zero by the software. We used the null and alternative hypotheses in statistical processing. The statistical process and data analysis were completed with consultation and cooperation from a statistician/biostatistician. The STROBE checklist was followed [21]. The data followed a normal distribution, and parametric statistical methods were employed. Descriptive statistics, including total counts, means, and standard deviations, were calculated. Hypotheses were tested using a student's *t*-test to compare the two groups. The Bonferroni correction was used to adjust *p*-values. Multiple hypothesis tests on the same data were performed to control the family-wise error rate (FWER), preventing an unacceptable number of false positives.

Results

The Bonferroni correction statistical method presented the adjusted alpha of 0.02 (α/k) to adjust the *p*-values as multiple hypothesis tests were performed on the same data to control the overall family-wise error rate (FWER), preventing an unacceptable number of false positives. A test was considered statistically significant when the *p*-value was less than the adjusted alpha 0.02 (α/k). All statistically significant results are marked 'yes' in Table 2–8.

Demographic information

A total of 190 results were included in the analysis. The youngest participant was 12 months old, and the oldest was 109 months old. The preschool age group ranged from 12 to 60 months, with 168 participants (88%; Table 2). The school-age group included 22 participants (12%; Table 2). Within the preschool group, female participants predominated, with 92 individuals (55%; n = 168; Table 2), while male participants accounted for 76 individuals (45%; n = 168; see Table 2). In the school-age group, eight participants were male (36%; n = 22; Table 2), and 14 were female (64%; n = 22; Table 2). None of the participants presented with broad gait patterns, developmental dysplasia of the hip (DDH), coxa valga, or coxa vara. Within the preschool group, three participants (2%; n = 168; Table 2) exhibited limping on the left lower limb, two (1%; n = 168; Table 2) showed right-sided tiptoeing, and six (4%; n = 168; Table 2) were identified with right leg length discrepancy (LLD). In-toeing and out-toeing were observed in both age groups (see Table 2). The preference for W-sitting was evident in both groups. Within the preschool group, 61 participants (36%; n = 168; Table 2) preferred W-sitting, while eight participants (36%; n = 22; Table 2) in the school-age group also exhibited this preference.

The FPI-6 results for preschool-aged children were divided into age groups based on milestones and changes in gait and foot development. The first age group, 12–15 months (n = 22; Table 3), did not exhibit pronation pathology but demonstrated differences between the right (M = 1.18, n = 11, Table 3) and left (M = 2.63, n = 11, Table 3) feet. The 16–24-month age group presented similar results, with a mean of 1.92 for the right foot (n = 27, Table 3) and 2.75 for the left foot (n = 27,

Table 2. Demographic information

Demographic information 12–60 months		Age group*		Sign test results	
		61–109 months	*p*-value	α/k*	
All (*n* = 190)		168 (88%)	22 (12%)	–	–
Gender	male	76 (45%)	8 (36%)	–	–
	female	92 (55%)	14 (64%)	–	–
DDH		0	0	–	–
Coxa Valga		0	0	–	–
Coxa Vara		0	0	–	–
W-sitting	yes	61 (36%)	8 (36%)	0.00	yes
Limping	left	3 (2%)	0	–	–
Tiptoeing	right	2 (1%)	0	–	–
LLD	right	6 (4%)	0	–	–
Wide base	yes	0	0	–	–
In-toeing	right	3 (2%)	1 (5%)	–	–
	bilateral	24 (14%)	7 (32%)	–	–
Out-toeing	right	4 (2%)	0	–	–
	left	2 (1%)	0	–	–
	bilateral	18 (11%)	1 (5%)	–	–

DDH – developmental dysplasia of the hip, LLD – leg length discrepancy LLD
* All results are described as the total number of results and %.
The Bonferroni correction statistical method presented the adjusted alpha of 0.02 (α/k)

Table 3. FPI-6 General score: 12–109 months*

Age (months)	Lower limb	Descriptive statistics results*				Sign test results	
		score					
		mean	high	low	*n*	*p*-value	α/k*
12–15	right	1.18	6	–8	11	–	–
	left	2.63	6	–5	11	–	–
	both	1.90	6	–8	22	–	–
16–24	right	1.92	8	–5	27	–	–
	left	2.75	8	–8	27	–	–
	both	2.27	8	–8	54	–	–
25–29	right	3.06	8	0	16	–	–
	left	3.00	8	0	16	–	–
	both	3.03	8	0	32	–	–
30–36	right	3.66	9	0	24	–	–
	left	4.50	11	0	24	–	–
	both	4.08	11	0	48	–	–
37–48	right	2.10	9	–4	47	–	–
	left	2.17	9	–4	47	–	–
	both	2.13	9	–4	94	–	–
49–60	right	1.23	9	–12	43	–	–
	left	1.23	9	–12	43	–	–
	both	1.23	9	–12	86	–	–
12–60	right	2.10	9	–12	168	0.00	yes
	left	2.36	9	–12	168	0.00	yes
	both	2.23	9	–12	336	–	–
61–109	right	2.77	12	–2	22	0.01	yes
	left	2.81	12	–2	22	0.01	yes
	both	2.79	12	–2	44	–	–

* All results are described as the total number of analysis sheets and descriptive statistics results.
The Bonferroni correction statistical method presented the adjusted alpha of 0.02 (α/k).

Table 3). These two groups showed the highest differences compared to other age groups. This increase on the left side suggests weight-bearing changes correlated with hand and side preference, as a right-handed child is likely to increase weight-bearing on the contralateral side (i.e., the left lower limb).

The 25–29-month age group exhibited an increased risk of foot pathology, with a mean score of *M* = 3.03 (*n* = 32, Table 3). These results were observed for both the right and left feet. Similar outcomes were observed in the 30–36-month group, with a mean score of *M* = 4.08 (*n* = 48, Table 3) and differences between the right (*M* = 3.66, *n* = 24, Table 3) and left (*M* = 4.5, *n* = 24, Table 3) feet. The age group (30–36 months) presented an increased risk of developing foot pathology due to developmental changes. In contrast, the age groups 37–48 months (*M* = 2.13, *n* = 94, Table 3) and 49–60 months (*M* = 1.23, *n* = 86, Table 3) exhibited a decreased risk of foot pathology, reaching minimal levels.

According to the FPI-6 results, the risk of developing foot pronation or supination was similar in the 12–15-month group, with the highest score of 6 and the lowest score of –8 (*n* = 22, Table 3). The highest risk of foot pronation was observed in the 16–24-month group, with scores ranging from –8 to 8 for the left foot (*n* = 47, Table 3). The 25–29-month group demonstrated significant risk, with scores ranging from 0 to 8 (*n* = 32, Table 3). This was followed by the 30–36-month group, which exhibited the highest score of 11 for the left foot (*n* = 24, Table 3) and the lowest score of 0.

The 37–48-month group presented with a maximum pronation score of 9 and a minimum of –4 (*n* = 94, Table 3). Notably, the 49–60-month group was the only group showing a possible risk of foot supination, with a lowest score of –12 and a pronation score of 9 (*n* = 86, Table 3).

The results indicate a low risk of foot pathology concerning W-sitting in the age range of 12 to 109 months (*n* = 22, n = 47, *n* = 32, *n* = 48, Table 3, 4). Despite this low risk, foot screening should still be considered a prudent measure.

The school-age group, from 61 to 109 months, presented with a slightly increased risk of foot pathology, with a mean of 2.79 (*n* = 44, Table 3), with almost no difference between the right, mean of 2.77 (*n* = 22, Table 3), and the left, mean of 2.81 (*n* = 22, Table 3), foot. The results for the highest and lowest marks presented a significant risk of developing foot pronation, with a high score of 12 (*n* = 44, Table 4), and a low risk of developing foot supination, with a low score of –2 (*n* = 44, Table 3).

Zebris FDM platform – additional results for preschool age group 12–60 months

Gait parameters for preschoolers, ages 12 to 60 months, are presented in Tables 6–9. The gait analysis was conducted using the Zebris FDM in the KASCH and PSU gait laboratories following company recommendations. The platform was placed in the laboratory with two metres of free space. Due to ongoing renovations, the height difference between the FDM platform and the floor was minimised by placing rugged mats within two metres to ensure a level surface. The non-slippery mat surfaces adhered to the hospital's approved guidelines for infection control. Start and finish points were marked to ensure consistent walking distance and parameters for all participants.

Some participants required multiple analyses due to misreadings caused by sudden stops or changes in direction. Only results from the start-to-finish points were included. All assessments were performed barefoot, and the platform was cleaned and disinfected between participants. The Zebris FDM results are divided into four tables: gait parameters (Table 5), butterfly results (Table 6), and maximum force results for the right (Table 7) and left (Table 8) lower limbs. Gait parameters (Table 5) describe individual gait phases, including local parameters such as foot rotation, step length, stride length, step width, and the stance and swing phases of the gait cycle. The stance phase is divided into these double-standing phases: loading response, roll-off, and mid-stance. Timing parameters include step time, stride time, cadence, and average speed.

Step length, measured in cm, was 31.24 (*SD* = 14.89) for the left foot and 31.76 (*SD* = 14.18) for the right foot (*n* = 169, Table 5). Foot rotation, measured in degrees, showed no inward rotation in the group, while outward rotation was observed with a mean of 5.36 (*SD* = 8.80) for the left foot and 5.73 (*SD* = 9.00) for the right foot (*n* = 169, Table 5). Step time, measured in seconds, was 0.58 (*SD* = 0.44) for the left foot and 0.61 (*SD* = 0.62) for the right foot (*n* = 169, Table 5). The stance phase, expressed as a percentage, showed a higher score for the left limb, with a mean of 66.86 (*SD* = 37.29) for the left foot and 64.17 (*SD* = 11.09) for the right foot (*n* = 169, Table 5).

The loading response phase, measured as a percentage, had a left mean of 14.79 (*SD* = 8.18) and a right mean of 15.76 (*SD* = 12.14) (*n* = 157, *n* = 150, Table 5). The mid-stance phase had a left mean of 66.86 (*SD* = 37.31) and a right mean of 64.18 (*SD* 11.10) (*n* = 169, Table 5). The pre-swing phase had a left mean of 17.65 (*SD* = 35.24) and a right mean of 15.06 (*SD* 9.41)

Table 4. FPI-6 descriptive statistics: 12–60 months

FPI-6	Descriptive statistics results*					Sign test results	
	n	mean	min.	max.	*SD*	*p*-value	α/k*
Talar head palpation right	168	0.26	–2.00	2.00	0.58	0.00	yes
Lateral malleolus curves right	168	0.23	–2.00	2.00	0.54	0.00	yes
Inv/ever of the calcaneus right	168	0.36	–2.00	2.00	0.62	0.00	yes
Tnj prominence right	168	0.51	–2.00	4.00	0.83	0.00	yes
Medial longit. arch right	168	0.58	–2.00	2.00	0.84	0.00	yes
Abd/add forefoot on rearfoot right	168	0.18	–2.00	2.00	0.58	0.00	yes
Talar head palpation left	168	0.34	–2.00	2.00	0.68	0.00	yes
Lateral malleolus curves left	167	0.29	–2.00	2.00	0.61	0.00	yes
Inv/ever calcaneus left	168	0.45	–2.00	2.00	0.76	0.00	yes
Tnj region prominence left	168	0.54	–2.00	2.00	0.81	0.00	yes
Medial longitudinal. arch left	168	0.58	–2.00	2.00	0.87	0.00	yes
Abd/add forefoot on rearfoot left	168	0.18	–2.00	2.00	0.59	0.00	yes

FPI-6 – Foot Posture Index Six, tnj – talonavicular joint, abd – abduction, add – adduction, inv – inversion, ever – eversion
* All results are presented as a total number, as well as mean and descriptive statistics.
The Bonferroni correction statistical method presented the adjusted alpha of 0.02 (α/k).

Table 5. Zebris FDM parameters, 12–60 months

Gait parameters	Side	Descriptive statistics results*					Sign test results	
		n	mean	min.	max.	*SD*	*p*-value	α/k*
Step length (cm)	left	169	31.24	–14.39	71.01	14.89	0.27	no
	right	169	31.76	–18.63	62.66	14.18	0.93	no
Foot rotation (°)	left	169	5.36	–24.56	33.73	8.80	0.35	no
	right	169	5.73	–20.42	34.69	9.00	0.01	yes
The step time (s)	left	169	0.58	0.18	3.32	0.44	1.00	no
	right	169	0.61	–1.25	6.47	0.62	0.53	no
Stance phase (%)	left	169	66.86	20.05	531.79	37.29	0.00	yes
	right	169	64.17	30.52	126.54	11.09	0.00	yes
Load response (%)	left	157	14.79	0.00	50.54	8.18	0.00	yes
	right	150	15.76	0.00	123.06	12.14	0.16	no
Single support (%)	left	157	35.08	0.00	72.09	8.39	0.00	yes
	right	150	34.36	0.00	74.57	9.19	0.05	no
Pre-swing (%)	left	169	17.62	0.00	444.14	35.24	0.01	yes
	right	169	15.06	0.00	59.58	9.41	0.00	yes
Swing phase (%)	left	169	33.13	–431.7	79.95	37.29	0.00	yes
	right	169	35.82	–26.54	69.47	11.09	0.00	yes
Toe off (%)	left	169	66.85	20.00	532.00	37.31	0.00	yes
	right	169	64.18	31.00	127.0	11.10	0.00	yes
Total double support (%)		169	31.44	0.00	335.53	28.59	0.00	yes
Stride length (cm)		169	62.16	–5.92	125.76	26.70	0.69	no
Stride time (s)		169	1.20	0.38	8.81	0.87	0.81	no
Step width (cm)		169	10.11	2.82	25.28	3.76	0.03	no
Cadence (steps/min)		169	129.76	27.47	313.97	44.19	1.00	no
Velocity (km/h)		169	2.38	0.07	7.98	1.35	0.06	no
Variability of velocity (%)		165	22.47	0.32	149.35	20.21	0.75	no

* All results are described as a total number, mean, and descriptive statistics.
The Bonferroni correction statistical method presented the adjusted alpha of 0.02 (α/k).

(*n* = 169, Table 5). The swing phase showed a left mean of 33.13 (*SD* = 37.20) and a right mean of 35.82 (*SD* = 11.09) (*n* = 169, Table 5).

Total double support, representing the sum of the loading response and pre-swing phases, had a mean of 31.44 (*SD* = 28.59) (*n* = 169, Table 5). Stride length, measured in cm, had a mean of 62.16 (*SD* = 26.70) (*n* = 169, Table 5). Stride time, measured in seconds, was 1.20 (*SD* = 0.87) (*n* = 169, Table 5). Cadence, expressed as steps per minute, was 129.76 (*SD* = 44.19) (*n* = 169, Table 5). The average gait speed, measured in km/hr, had a mean of 2.38 (*SD* = 1.35) (*n* = 169, Table 5).

The next phase of the Zebris FDM analysis involved creating a butterfly diagram, with the results presented in Table 6. This part analysed the course of the centre of pressure (COP) during the selected step cycles (Table 6).

The 'Length of the gait line' parameter is characterised by the position of the COP, considering only the ground contacts of one side of the body. This parameter covers the progression of the COP across all steps recorded on one side. The left side had a mean of 122.3 (*n* = 169, *SD* = 48.94, Table 6), while the right had a mean of 118.2 (*n* = 169, *SD* = 45.38, Table 6).

The 'Single support line' parameter is part of the mid-stance phase and corresponds to the average length of the lines showing the progression of the COP of one side of the body, including all ground contacts. For the 12–60-month age group, the mean for the left side was 60.15 (*n* = 169, *SD* = 35.87, Table 6), while the right side had a mean of 53.45 (*n* = 169, *SD* = 36.81, Table 6).

The 'Anterior/posterior position' parameter describes the forward or backward shift of the COP intersection points in chronological sequence, considering all the steps. The initial or zero stand is the rearmost point where the heel contacts the ground, with a mean of 103.4 (*n* = 169, *SD* = 36.29, Table 6). 'Anterior/posterior variability' refers to the standard deviation in the anterior/posterior position resulting from considering all steps.

The 'Lateral symmetry' parameter describes the left and/or right deviation of the COP intersection point in chronological distribution, considering all steps. A negative value indicates a shift to the left, while a positive value indicates a change to the right. This group showed a negative value, indicating a shift to the left, with a mean of –4.37 (*n* = 169, *SD* = 14.48, Table 6).

The final part of the Zebris FDM analysis involved the gait lines for the left and right lower limbs. The lines, representing the points of force application, are presented separately for each foot in Tables 7 and 8. The results for the force application points are shown separately for each group and limb in these tables.

Table 6. Butterfly parameters: 12–60 months

Butterfly parameters	Side	Descriptive statistics results*					Sign test results	
		n	mean	min.	max.	*SD*	*p*-value	α/k*
Gait line length	left	169	122.3	26.00	285.0	48.94	0.87	no
	right	169	118.2	36.00	287.0	45.38	1.00	no
Single support line	left	169	60.15	0.00	148.0	35.87	0.00	yes
	right	169	53.45	0.00	209.0	36.81	0.02	no
Ant/post position		169	103.4	52.00	264.0	36.29	0.01	yes
Ant/post variability		169	11.99	0.00	100.0	15.55	0.75	no
Lateral symmetry		169	–4.37	–44.00	39.00	14.48	0.31	no

* All results are described as a total number, mean, and descriptive statistics.
The Bonferroni correction statistical method presented the adjusted alpha of 0.02 (α/k).

Table 7. Zebris FDM – Gait line, right limb, 12–60 months

Gait line, right limb	Descriptive statistics results*					Sign test results	
	n	mean	min.	max.	*SD*	*p*-value	α/k*
Max force 1 (N)	155	235.70	35.10	1157.8	181.07	0.00	yes
Max force 1 time (%)	155	19.40	2.00	42.00	8.61	0.93	no
Max force 2 (N)	140	214.41	21.00	1185.1	185.70	0.33	no
Max force 2 time (%)	140	43.88	27.00	92.00	7.55	0.85	no

* All results are presented as a total number, as well as mean and descriptive statistics.
The Bonferroni correction statistical method presented the adjusted alpha of 0.02 (α/k).

Table 8. Zebris FDM – Gait line, left limb, 12–60 months

Gait line, left limb	Descriptive statistics results*					Sign test results	
	n	mean	min.	max.	*SD*	*p*-value	α/k*
Max force 1 (N)	156	227.45	35.70	1187.0	173.54	0.00	yes
Max force 1 time (%)	156	20.48	2.00	171.00	14.94	0.86	no
Max force 2 (N)	143	213.11	32.600	1198.4	181.37	0.08	no
Max force 2 time (%)	143	43.45	24.00	69.00	6.41	0.92	no

* All results are presented as a total number, as well as mean and descriptive statistics.
The Bonferroni correction statistical method presented the adjusted alpha of 0.02 (α/k).

Average maximum pressure diagrams present the averaged and normalised pressure curves, while the average force diagram displays the average vertical reaction force. These force parameters are divided into two measurements for the right and left lower limbs (Tables 7 and 9). The right limb's mean was 235.7 (*n* = 155, *SD* = 181.07, Table 7), and the left limb's mean was 227.4 (*n* = 156, *SD* = 173.5, Table 8).

Based on the results previously presented, the hypotheses proposed in the study can be analysed:

Hypothesis 1: It is assumed that preschool children are at a higher risk of foot pronation than school-age children.

Result: According to the results obtained, this hypothesis was confirmed, as the preschool-age group (12–60 months) showed a higher risk of developing foot pathologies or deformities compared to children over 61 months of age (eta-squared (η^2): 0.08, Cohen's *d*: 0.53, *p*-value > 0.05, α/k* > 0.016), supporting significant results.

Hypothesis 2: It is assumed that preschool children prefer to sit in the W-sitting posture.

Result: This hypothesis was also confirmed, as the W-sitting posture was observed in both age groups, with an incidence of 36% (eta-squared (η^2): 0.08, Cohen's *d*: 0.56).

Hypothesis 3: It is assumed that there is a gait difference between the right and left lower limbs in preschool children.

Result: The hypothesis was supported. Preschool participants presented an elevated risk of developing deformities or pathologies in the left foot (Eta-squared (η^2): 0.05, Cohen's *d*: 0.26).

Discussion

This research examined the prevalence of W-sitting, gait patterns, and foot abnormalities in preschool and school-aged children. The study aimed to investigate the potential relationship between these factors and children's overall physical development. The main findings of the present study were that W-sitting posture preference was prevalent in 36% of the participants. Some children presented with leg length discrepancies or a tendency to walk on their tiptoes. Preschoolers aged 12 to 36 months were found to be at a higher risk of developing foot pathologies than the school-aged group, particularly those in the 25 to 36-month age range.

When comparing the results of this study with other research on foot posture and gait in young children, several interesting parallels emerge. Similar to the findings of Oleksy et al. [9] and Gijon-Nogueron et al. [7], our study found a prevalence of foot pronation in young children, particularly in the 12–60-month age group. Specifically, the right foot had a lower mean FPI-6 score compared to the left foot, which was not defined in the works of Oleksy et al. [9] or Gijon-Nogueron et al. [7]. These studies highlight the variability in FPI-6 scores across different countries, with significant differences found between the Spanish, UK, and Australian cohorts [23, 24].

The reported mean FPI-6 values for the preschool age group in our study (mean 2.10 for the right foot and 2.36 for the left foot) are comparable to the results presented by Gijon-Nogueron et al. [7], who found an average score of 4.00 in Spanish children. However, it is essential to note that our study did not find significant foot abnormalities or pathologies, aligning with the findings of Oleksy et al. [9], who also found no pronounced deformities in the feet of the children in their study. This absence of pathology in our cohort supports the idea that the FPI-6 can be a practical screening appliance for identifying early signs of abnormal foot posture, as discussed in previous studies [7].

Furthermore, the differences in gait between the groups in our study were consistent with the literature, suggesting that gross motor skills, such as walking, undergo substantial development during early childhood [13, 27]. The gait pattern of our sample aligns with the general developmental trajectory of young children [13]. This finding does not discount the importance of early intervention when dealing with conditions such as hip developmental dysplasia (DDH), which can affect gait and foot posture [28, 29]. As highlighted by Vasilcova et al. [30], the presence of DDH in early childhood often leads to compensation in movement patterns, which may impact the child's overall motor development and foot control, underscoring the relevance of careful monitoring of gait and foot posture at this stage.

The studies by Bertsch et al. [3] and Gimunová et al. [13] presented pathologies such as flatfoot, linking an increased footprint area with potential developmental issues. We recognise that further research could expand on these findings by incorporating detailed footprint assessments, which could provide more insight into the link between foot posture and potential developmental conditions such as DDH.

This study presents limitations, including the use of a convenience sample, which may affect the generalisability of the findings. The study was also constrained by limited sample sizes in certain age groups and disruptions caused by the COVID-19 pandemic, affecting patient availability. Moreover, the study did not explore other diagnoses, such as clubfoot or developmental dysplasia of the hip, which could influence foot posture. Future research should consider conducting longitudinal studies to track changes in foot posture over time and investigate the relationship between early walking milestones and foot alignment. Research could also investigate the impact of other conditions, such as DDH and other orthopaedic or neurological diagnoses, on gait and assess the effectiveness of interventions like orthotics or physical therapy. Standardising physiotherapist training in gait assessment could improve the reliability of foot posture screenings.

Conclusions

This study supports the value of early screening and assessment of foot posture and gait in young children, particularly those without significant comorbidities. The findings demonstrate that the FPI-6 is an effective tool for detecting subtle abnormalities in foot posture.

The study also highlights the importance of physiotherapists in screening, treatment, and evaluation. Targeted research in this area will contribute to refining assessment practices and creating more effective tools for paediatric physiotherapy services. The results from the Zebris FDM software further emphasised the diversity of gait patterns between preschool and school-age children, revealing the possible impact of factors like W-sitting on foot posture. While the Saudi participants showed a low risk of developing foot deformities, regular assessment remains crucial for preventing complications that could hinder development.

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Ethical approval

The research related to human use complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and was approved by the Institutional Review Board at King Abdullah International Medical Research Centre in Riyadh, Saudi Arabia and was registered with reference number: No. IRBC/1747/21, study No. SP21R/364/06.

The Masaryk University Research Ethics Committee reviewed the application to conduct the research project with reference number EKV-2021-018.

The STROBE checklist was followed.

Informed consent

Informed consent was obtained from all individuals included in this study.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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