Heliyon 8 (2022) e10984

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Research article

Dynamic knee valgus prevalence in children and its association with pain intensity, foot mobility, and sex— A cross-sectional study

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ARTICLE INFO

Keywords:
Knee
Foot
Children
Knee pain

ABSTRACT

Introduction: Knee pain can impact the performance of activities and sports participation in children. Dynamic knee valgus is a movement pattern commonly related to health conditions that may be associated with sex and foot kinematics in children.

Objective: To assess the prevalence of dynamic knee valgus and its relationship with foot mobility, sex, and knee pain in children.

Method: A cross-sectional observational study was carried out with 144 children (10–18 years old). The pain level was investigated using the Visual Analog Pain Scale and categorized into no pain/minor pain (≤2 cm), moderate pain (3–4,9 cm), and severe pain (≥5.0 cm). Foot mobility was assessed using the adapted navicular drop test and categorized into poor/adequate foot mobility (0.0 cm–0.9 cm) and greater foot mobility (≥1.0 cm). The dynamic knee valgus presence was checked using the step-down test. The association analysis was performed using simple tabulation considering the cluster effect. The Prevalence Ratios and the respective confidence intervals (95%) were estimated from Multiple Poisson Regression with robust variance. A significance level of 5% was adopted.

Results: The dynamic knee valgus prevalence was 26.3% and 26.9% in the right and left lower limbs, respectively. Females presented greater dynamic knee valgus frequency in the left lower limb than males. The dynamic knee valgus presence in males was associated with foot mobility in right ($p = 0.001$) (Prevalence Ratio: 9.33 Confidence Interval: 2.93–29.72) and left lower limbs ($p = 0.003$) (Prevalence Ratio: 6.25 Confidence Interval: 1.7–22.62).

Conclusion: Male and female children showed different relationships of the analyzed factors, suggesting that characteristics related to sex may impact the aspects linked to dynamic knee in children.

1. Introduction

The knee is the most common injured joint throughout life [1]. Specifically, in adolescents, a study showed a prevalence of 22% of knee pain [2]. Orthopedic injuries have a relevant impact on the children's life [3]. They can reduce their functional capacity to practice sports [3], limiting or interrupting the performance of daily activities and consequently, also impacting their academic performance [4, 5]. In addition, the presence of knee injuries throughout life is considered a significant factor for the development of osteoarthritis in this joint, the rheumatic disease more common in the elderly [6]. Osteoarthritis has a considerable impact on individual health and, due to its high prevalence in the elderly, it is characterized as a public health problem [6]. Thus, understanding the factors related to the development of knee pain in children can contribute to planning preventive and treatment strategies that would impact health in the short and long term.

Dynamic knee valgus (DV) is a movement pattern that has been associated with injuries, such as anterior cruciate ligament tear [7, 8],

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https://doi.org/10.1016/j.heliyon.2022.e10984
Received 28 March 2022; Received in revised form 20 July 2022; Accepted 3 October 2022

Patellofemoral Pain Syndrome (PFPS), and iliotibial tract injuries [8, 9, 10, 11]. The DV can be observed during weight-bearing activities, such as the single-leg squat [12, 13]. This movement pattern is characterized as the combination of excessive hip medial rotation and adduction, knee abduction, and foot protonation, leading to the medial displacement of the knee about the foot [14, 15]. A higher prevalence of DV in adolescents has been associated with females than males [16, 17], and this relationship is more significant as children get older [18]. Besides, foot kinematics has been described as another risk factor for developing knee injuries [1]. For example, greater foot mobility has been observed in those with PFPS compared to healthy individuals [14], and it may be related to anterior cruciate ligament injuries in soccer players [19, 20].

Currently, it is known that DV is associated with an increased risk of orthopedic injuries and prolonging painful conditions. Few studies have investigated the prevalence of DV and its association with greater foot mobility, sex, and the presence of knee pain. Also, population-based epidemiological studies that assess these factors in children are scarce in the literature. Thus, the present study aimed to evaluate the prevalence of DV and its relationship with greater foot mobility, sex, and knee pain in children.

2. Methods

A cross-sectional observational study was carried out with 144 children (72 males aged 15.03 ± 2.40 years and 72 females aged 15.07 ± 2.10 years) enrolled in elementary or high school public schools in the city of Natal/RN during 2019 and 2020. The inclusion criteria were age between 10 and 18 years and not having orthopedic, rheumatic, or neurological problems. The exclusion criteria were children with physical or mental disabilities or with another disease that prevented maintaining the orthostatic position. The sampling was probabilistic, stratified, and proportional to the total number of students in each school, with a random draw using the numbered attendance list for each classroom. Children from 17 schools in Natal/RN participated in the research. The University Research Ethics Committee approved the investigation (CAAE: 07389318.1.0000.5292) and all the participants and their legal guardians signed an informed consent form.

2.1. Procedures

Initially, descriptive data were collected. Also, the pain level was registered using the Visual Analog Pain Scale (VAS) [18], and the answers were categorized as no pain/minor pain (0–2 cm), moderate pain (3–4.9 cm), and severe pain (>5 cm) [21]. Then, foot mobility was assessed using the adapted Navicular Drop Test (TQN) [22, 23]. This test begins with the participant sitting with the feet on the floor [22]. In this position, a point was marked with a pen on the palpable region of the navicular's tuberosity [22]. Then, the vertical distance of the navicular's tuberosity was measured [22]. Subsequently, the participant was instructed to stand up in double support, and the vertical distance from the navicular's tuberosity to the ground was measured again [22, 23]. The difference between the two measurements was recorded in millimeters. A single measurement was taken by only one physical therapist examiner, who performed previous measurement training. This test is described in the literature as showing good clinimetric properties [22]. For data analysis, the results of this test were categorized as poor/adequate foot mobility (0.0 cm–0.9 cm) and greater foot mobility (≥1.0 cm) [24, 25].

The DV presence was assessed according to the test described by Piva et al. [12]. First, the participant stood on a single leg on a 20 cm height step, with both hands on the waist, knee extended, and the foot close to the edge [12]. Then, the examiner asked the participant to touch the contralateral heel to the floor (i.e., without unloading the weight) and subsequently, returning the supporting lower limb to the initial position [11, 12]. The test assesses each lower limb separately during five repetitions [11, 12, 26]. The test is considered positive (i.e., presence of DV) if the knee deviates medially, crossing the medial edge of the supporting foot [12]. The judgment was carried out by a single physical therapist examiner, who had previously trained this measure. The literature also show that the test presents good clinimetric properties [11]. All procedures were performed in just one meeting during the school period, lasting approximately 30 min.

2.2. Statistical analysis

Demographic characteristics (sex and age) and the outcome from the performed tests were described using simple tabulations [27] considering the complex sampling design [28]. The prevalence of each variable was calculated from the complex sampling design, including weights and cluster effects [28]. For the association analysis between the DV and each independent variable (sex, foot mobility, age group, and knee pain presence), the Prevalence Ratios (PR) and the respective 95% confidence intervals (95% CI) of the outcome were estimated from Multiple Poisson Regression with robust variance and according to the participant' sex. A significance level of 5% ($\alpha < 0.05$) was adopted. For the analysis of demographic characteristics and PR we used de SPSS (version 25) and for the Multiple Poisson Regression the Stata (Stata/IC 12.0).

3. Results

The description of the investigated variables are presented in Table 1. The prevalence of DV was 26.3% (95% CI: 18–35) in and 26.9% (95 CI %: 19–36.5) in the right and left lower limb, respectively. The prevalence of greater foot mobility was 29.1% (95% CI: 20.2–40.1) and 20.4% (95% CI: 14–28.7) in the right and left lower limb, respectively. Severe knee pain was present in 17.2% (95% CI: 8.7–31.3) of the sample.

Table 1. Sample estimates of the main categorical variables. Prevalence ratios and the respective 95% CI.

	Prevalence		
Variable	*N*	% (#)	95% CI
Sex			
Male	72	51.4	41.6–61.1
Female	72	48.6	38.9–58.4
Right Dynamic Knee Valgus			
Absent	101	73.7	58.8–84.7
Present	43	26.3	15.3–41.2
Left Dynamic Knee Valgus			
Absent	102	73.1	57.9–84.4
Present	42	26.9	15.6–42.1
Age Group			
10–12 years old	22	22.7	11.8–39.1
13–15 years old	54	38.4	26.0–52.5
16–18 years old	68	38.9	23.3–57.2
Pain Level (VAS)			
No pain/minor pain	85	59.8	49.5–69.4
Moderate pain	33	23.0	18.1–28.6
Severe pain	26	17.2	8.7–31.3
Right Foot Mobility (TQN)			
Poor/adequate foot mobility	105	70.9	59.9–79.8
Greater foot mobility	39	29.1	20.2–40.1
Left Foot Mobility (TQN)			
Poor/adequate foot mobility	110	79.6	71.3–86.0
Greater foot mobility	34	20.4	14.0–28.7

Note: *n* = Number of participants evaluated; 95% CI = 95% Confidence Interval; VAS = Visual Analog Pain Scale; TQN = Adapted Navicular Drop Test; (#) = The percentage was obtained after weighting and cluster effect. It does not correspond to the same proportion of the sample.

Table 2. - Prevalence of variables DV and greater foot mobility according to sex. Prevalence Ratios and the respective 95% CI.

	Male		Female		P value	PR (95% CI)
	Present	Absent	Present	Absent		
	n# (%##)	*n*# (%##)	*n*# (%##)	*n*# (%##)		
Dynamic Knee Valgus						
Right	21 (24.9)	51 (75.1)	22 (27.7)	50 (72.3)	0.85	1.0 (0.7–1.4)
Left	15 (18.2)	57 (81.1)	27 (36.0)	45 (64.0)	0.02*	1.4 (1.0–1.9)
Greater foot mobility						
Right	23 (34.3)	49 (65.7)	16 (23.6)	56 (76.4)	0.18	0.7 (0.5–1.1)
Left	14 (19.9)	58 (80.1)	20 (20.9)	52 (79.1)	0.23	1.2 (0.8–1.7)

Note: PR = Prevalence Ratio; 95% CI = 95% Confidence Interval; *n* = Number of participants evaluated; # = The number of participants evaluated; ## = The percentage was obtained after the weighting and clustering effect. It does not correspond to the same proportion of the sample; * = $p \leq 0.05$.

Table 2 shows the prevalence of the variables according to sex. The results showed that only the DV in the left lower limb presented a significant difference (PR: 1.4 95% CI: 1.0–1.9) between the sexes, in which the frequency was higher in females than in males.

Tables 3 and 4 show the prevalence of DV in the participants according to sex and its association with the following variables: foot mobility, pain level, and age group. The relationship was significant ($p = 0.003$) between foot mobility and the presence of the right (PR: 9.33 95% CI: 2.93–29.72) and left (PR: 6.25 95% CI: 1.7–22.62) DV in males (Table 3). There was no statistically significant association between the prevalence of DV and age group in males and females (Table 4).

4. Discussion

This study investigated the DV prevalence in children and its association with foot mobility, pain level, age group, and sex. Male and female children showed distinct relationships. Females presented greater DV frequency in the left lower limb than males. Besides, lower foot mobility was associated with absence of DV only in males. A marginal effect was observed of greater frequency of females between 13 to 15 years old who did not present DV in the right lower limb. The other investigated outcomes were not associated with DV in males or females. Thus, characteristics related to sex may impact the factors related to DV in children.

The DV was more prevalent in the left lower limb of females than in males. This result corroborates other findings showing that female children had greater hip adduction and medial rotation and knee abduction during the single-leg squat than males [16, 29]. Similar findings have also been found in adults [13]. Thus, sex characteristics seem to be determinant for DV independent of age. Possibly, sex differences related to muscle cross-sectional area, torque generation capacity [16], and bone alignment (e.g., femoral neck anteversion angle) [18] should be determinant in the adopted lower limb motion during weight-bearing tasks. It is noteworthy that the greater prevalence of DV in females than males was observed only in the left lower limb. Despite not being assessed in the current study, limb dominance may contribute to this result. The left leg tends to be the non-dominant one, and thus, typically, this limb is related to the lower capacity to generate torque [29]. Therefore, characteristics related to the lower capacity of the musculoskeletal system to deal with the torques during weight-bearing tasks by female children, especially on the non-dominant limb, may explain our findings. This proposed explanation is speculative at this moment and requires future investigations to confirm it.

Foot mobility showed a positive association with the DV only in males. Greater foot mobility has been associated with PFPS in children aged 16–18 years [7], patellofemoral osteoarthritis in adults [14], DV in healthy adults [15], and described as a risk factor for the development of PFPS in the military personnel [30]. The greater midfoot mobility is associated with increases in lower leg medial rotation, leading to excessive knee abduction and medial rotation, together with an increase in hip medial rotation, typical joint movements linked to DV [14, 15, 19]. The observed association only in males may suggest that these mechanical couplings between midfoot position and lower limb kinematics are determinant for this sex. Thus, the musculoskeletal factors associated with the DV may differ between sexes and should be considered during physical therapy evaluations. The physical therapist must consider which sex-related factors may influence the biomechanics of the lower limbs.

The observed non-association between foot mobility and DV in females corroborates other findings [31]. It is noteworthy that previous studies have found differences in the eccentric strength of hip muscles between sexes, in which female adolescents presented lower strength than males [16]. Another study also observed lower activation of gluteus medius in females than males [17]. Thus, a possible explanation is that the proximal lower limb factors (e.g., hip muscles) may be more

Table 3. - Association between DV and foot mobility, pain level, and age group in males. Prevalence Ratios, respective 95% CI and Multiple Poisson Regression.

	Right Dynamic Knee Valgus		P value	PR (95% CI)
	Present	Absent		
	n# (%##)	*n*# (%##)		
Right Foot Mobility (TQN)				
Poor/adequate foot mobility	7 (11,5)	42 (88.5)		1
Greater foot mobility	14 (50.6)	9 (49.4)	<0.01*	9,3 (2.93 – 29,72)
Pain Level (VAS)				
No pain/Minor pain	11 (18.4)	37 (81.6)		1
Moderate pain	6 (42.6)	8 (57.2)	0.12	1.8 (0.8–4.1)
Severe pain	4 (36.4)	6 (63.6)	0.23	1.7 (0.6–4.4)
Age Group				
10–12 years old	5 (38.1)	6 (61.9)		1
13–15 years old	9 (26.5)	19 (73.5)	0.07	0.4 (0.2–1.0)
16–18 years old	7 (17)	26 (83)	0.10	0.4 (0.1–1.1)
	Left Dynamic Knee Valgus			
	Present	Absent		
	n# (%##)	*n*# (%##)		
Left Foot Mobility (TQN)				
Poor/adequate foot mobility	8 (11.4)	50 (88.6)		1
Greater foot mobility	7 (45.4)	7 (54.6)	<0.01*	6.2 (1.7– 22.62)
Pain Level (VAS)				
No pain/Minor pain	9 (14)	39 (86)		1
Moderate pain	5 (39.6)	9 (60.4)	0.17	1.9 (0.7–4.7)
Severe pain	1 (9.5)	9 (90.5)	0.53	0.5 (0.7–3.8)
Age Group				
10–12 years old	5 (36)	6 (64)		1
13–15 years old	4 (13.9)	24 (86.1)	0.50	0.7 (0.2–2.0)
16–18 years old	6 (14.5)	27 (85.5)	0.10	0.4 (0.1–1.2)

Note: TQN = Adapted Navicular Drop Test.; VAS = Visual Analog Pain Scale; PR = Prevalence Ratio; 95% CI = 95% Confidence Interval; *n* = Number of participants evaluated; # = The number of participants evaluated; ## = The percentage was obtained after the weighting and clustering effect. It does not correspond to the same proportion of the sample; * = $p \leq 0.05$.

Table 4. Association between DV and foot mobility, pain level, and age group in females. Prevalence Ratios, respective 95% CI and Multiple Poisson Regression.

	Right Dynamic Knee Valgus		P value	PR (95% CI)
	Present	Absent		
	n# (%##)	*n*# (%##)		
Right Foot Mobility (TQN)				
Poor/adequate foot mobility	15 (21.9)	41 (78.1)		1
Greater foot mobility	7 (46.3)	9 (53.7)	0.10	2.1 (0.67 – 6.72)
Pain Level (VAS)				
No pain/Minor pain	11 (76.5)	26 (23.5)		1
Moderate pain	4 (19.4)	14 (80.6)	0.57	0.7 (0.2–2.0)
Severe pain	6 (42.6)	10 (57.4)	0.57	1.2 (0.5–2.8)
Age group				
10–12 years old	5 (29.3)	6 (70.7)		1
13–15 years old	6 (31.1)	20 (68.9)	0.05*	0.4 (0.1–1.0)
16–18 years old	10 (23.5)	25 (76.5)	0.09	0.5 (0.2–1.1)
	Left Dynamic Knee Valgus			
	Present	Absent		
	n# (%##)	*n*# (%##)		
Left Foot Mobility (TQN)				
Poor/adequate foot mobility	17 (31)	35 (69)		1
Greater foot mobility	10 (55.1)	10 (44.9)	0.17	2.0 (0.72−5.88)
Pain Level (VAS)				
No pain/Minor pain	10 (20.1)	27 (79.1)		1
Moderate pain	8 (32.4)	10 (67.6)	0.19	1.6 (0.7–3.4)
Severe pain	8 (69.4)	8 (30.6)	0.09	1.8 (0.8–3.8)
Age Group				
10–12 years old	5 (25)	6 (75)		1
13–15 years old	11 (45.4)	15 (54.6)	0.80	0.9 (0.4–2.0)
16–18 years old	11 (35.6)	24 (64.4)	0.30	0.6 (0.3–1.5)

Note: TQN = Adapted Navicular Drop Test.; VAS = Visual Analog Pain Scale; PR = Prevalence Ratio; 95% CI = 95% Confidence Interval; # = The number of participants evaluated; ## = The percentage was obtained after the weighting and clustering effect. It does not correspond to the same proportion of the sample; * = $p \leq 0.05$.

determinant than distal factors (e.g., foot mobility) for female children. Furthermore, together with lower performance of hip muscles, quadriceps weakness was related to the developing of PFPS in adults [32]. Probably, females would present greater benefits of a training program focusing on increasing the capacity of the hip and knee muscles to deal with the stresses of closed chain tasks.

Another finding was the absence of association between the DV and the presence of knee pain and age group in both sexes. Despite not being associated in the current transversal design study, both factors may be relevant to longitudinal followings. The knee pain reported by part of the sample may predispose to the development of health conditions in the joint. Besides, previous studies suggested that sexual maturation may impact the knee motion, especially in females, due to changes in the neuromuscular system [18]. Future prospective studies may consider whether the reported knee pain level and the knee motion in children changes during the teenage years and if these factors are associated with a greater risk to develop health conditions.

Dynamic lower limb alignment in children is likely to result from the combination of several factors, not limited to those investigated in the current study. Other non-investigated factors, such as muscle strength, level of physical activity, sexual maturation, and lower limb dominance, may be associated with DV. Future studies can verify whether these factors are associated and present a greater contribution to DV in children.

Considering the finding that about 25% of children presented DV and the results of other studies linking DV to health conditions, a preventive approach should be considered for children. A possibility could be the inclusion of this approach in primary health care [34]. The physical therapist can be the professional of choice for screening, preventing, and treating young individuals who present risk factors for developing musculoskeletal diseases in the lower limbs and minimizing future damage, and promoting healthy growth for the young person.

5. Conclusion

Male and female children presented different relationships of factors linked to DV. Females presented greater DV prevalence in the left lower limb than males. Besides, the lower foot mobility was associated with the absence of DV only in males. Thus, characteristics related to sex may impact the factors related to DV in children.

Declarations

Author contribution statement

Sanchis: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Lopes and Assis: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Catão: Performed the experiments; Wrote the paper.

Ribeiro: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Roncalli: Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data.

Funding statement

This work was supported by Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES).

Data availability statement

No data was used for the research described in the article.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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