Received: 04-08-2022 | **Accepted:** 22-09-2022
DOI: 10.54005/geneltip.1155681

ORIGINAL ARTICLE

Do Body Mass Index, Q Angle, and Pes Planus Affect Walking Age in Children with Down Syndrome and Their Typically Developing Peers?

Down Sendromlu Çocuklarda ve Tipik Gelişime Sahip Akranlarında Vücut Kitle İndeksi, Q Açısı ve Pes Planus Yürüme Yaşını Etkiler Mi?

[1]Güliz Ertekın, [2]Ismihan Ilknur Uysal, [3]Mehmet Sinan Iyısoy

[1]Physiotherapist, Konya, Turkey
[2]Necmettin Erbakan University, Meram Medical School, Department of Anatomy, Konya, Turkey
[3]Necmettin Erbakan University, Meram Medical School, Department of Medical Education and Informatics, Konya, Turkey

Correspondence

Ismihan Ilknur Uysal, Necmettin Erbakan University, Meram Medical School, Department of Anatomy, Konya, Turkey.

E-Mail: uysali@yahoo.com

NOTE: The study was presented orally at the 20th National Anatomy Congress (27-31 August, Istanbul).

How to cite ?

Ertekin G. , Uysal İ. İ. , İyisoy M. S. Do Body Mass Index, Q Angle, and Pes Planus Affect Walking Age in Children with Down Syndrome and Their Typically Developing Peers?. Genel Tıp Dergisi. 2022; 32(5): 571-576

ABSTRACT

Objective: To investigate the effects of body mass index (BMI), quadriceps angle (Q0) and pes planus on walking age in children with Down syndrome (DS) and typically developing peers.
Methods: Bodyweight, height and Q0 were measured and footprints were obtained in 50 children with DS and 50 typically developing children (control), ages between 2-6 years. BMI and Staheli index (SI) were calculated.
Results: The mean walking age was 26±8 months in the DS group and 12±2 months in the control group (p<0.0001). While BMI was 85 percent in all age groups in girls in the DS group, it increased with age in boys this group. SI was 1.17±0.28 in the DS group and 0.93±0.04 in the control group (p<0.001). Although there was no significant relationship between walking age and BMI, Q0, pes planus, the difference in walking age between the two groups decreased statistically as Q0 increased (p<0.001).
Conclusion: In the DS group, regular monitoring of BMI, keeping it within healthy limits, and adding exercises related to Q0 and pes planus to physical therapy programs will reduce the delay in walking age.

Keywords: Body mass index, Down syndrome, Pes planus, Q angle, Walking age

ÖZ

Amaç: Down sendromlu (DS) olan çocuklar ve tipik gelişime sahip yaşıtlarında vücut kitle indeksi (VKİ), kuadriseps açısı (Q0) ve pes planusun yürüme yaşı üzerine etkilerini araştırmak.
Yöntem: Yaşları 2-6 arasında 50 DS'lu çocuk (DS grubu) ve 50 tipik gelişim gösteren çocukda (kontrol grubu) vücut ağırlığı, boy uzunluğu ve Q açısı ölçüldü ve ayak izleri elde edildi. VKİ ve Staheli indeksi (SI) hesaplandı.
Bulgular: DS grubunda ortalama yürüme yaşı 26±8 ay, kontrol grubunda 12±2 ay idi (p<0.0001). VKİ, DS grubundaki kız çocuklarında tüm yaş gruplarında %85 iken, bu gruptaki erkek çocuklarda yaşla birlikte artış gösterdi. SI, DS grubunda 1.17±0.28 ve kontrol grubunda 0.93±0.04 idi (p<0.001). Yürüme yaşı ile VKİ, Q0, pes planus arasında anlamlı bir ilişki olmamasına rağmen, Q0 arttıkça iki grup arasındaki yürüme yaşı farkı istatistiksel olarak anlamlı azaldı (p<0,001).
Sonuç: DS grubunda VKİ'nin düzenli izlenmesi, sağlıklı sınırlarda tutulması ve fizik tedavi programlarına Q0 ve pes planus ile ilgili egzersizlerin eklenmesi yürüme yaşındaki gecikmeyi azaltacaktır.

Anahtar Kelimeler: Down sendromu, Pes planus, Q açısı, Vücut kitle indeksi, Yürüme yaşı

Introduction

Down syndrome (DS) is a genetic anomaly that results from the extra presence of all or part of the 21st chromosome, with common features as well as remarkable differences according to each individual (1). It is characterized by structural, mental and organismal changes that cause mental retardation and delay in motor performance. Often these changes are accompanied by a range of medical problems, including cardiac and respiratory problems (2, 3). Although the incidence varies by ethnicity and geographic region, DS occurs in about 1 in 800 births worldwide (4).

From early childhood to adulthood, individuals with DS continue to show deficits in the motor areas of postural control and movement skills. These deficiencies may have a causal link with delays in reaching motor development milestones (independent walking, climbing stairs) in children (2, 5, 6). Although the neuropathological basis of motor dysfunction in DS is unknown, cerebellar dysfunction, delayed myelination, proprioceptive and vestibular deficits have been suggested as possible causes (2).

The available evidence indicates that overweight and obesity in individuals with DS begin in late infancy and remain evident over the years. It has also been reported that the degree of overweight and obesity in children and adolescents with DS varies according to the clinical characteristics specific to that individual (7-9).

In the literature, it has been stated that normally developing children sit without support at 7 months and begin walking independently at 12 months,

whereas children with DS sit at 15 months and walk at 30 months (10). It is also stated that joint laxity and hypotonia, which are common in DS children, increase the risks of some musculoskeletal disorders and are associated with delay in walking (11). Pes planus, which is considered one of these disorders, is observed at a higher rate (60-88%) in children with DS than in children with normal development. There are studies investigating the effect of pes planus on gait pattern in children with DS (2, 11, 12).

Quadriceps (Q) angle is a measurement index used to evaluate the functions of the knee joint and patellofemoral joint and the etiology of patellofemoral pain (13-16). Q angle is defined as the angle between two axes drawn in the frontal plane, from anterior superior iliac spine to the mid-point of patella, and from the mid-point of patella to tibial tuberosity (17). It is considered normal that the Q angle value is between 8°-15° in healthy adult males and between 12°-19° in females. The rate of deviation of this angle from normal increases the risk of skeletal-muscle problems in the lower extremities of the people (15,18). Recently, studies investigating the relationship between Q angle and patella femoral instability, genu varum-valgum and cerebral palsy especially in children and adolescents have attracted attention (19, 20). However, a study on the measurement and evaluation of the Q angle in children with DS could not be found.

The aim of this study is to investigate the effects of some parameters (body mass index [BMI], pes planus and Q angle), each of which has been the subject of different studies, on the age of walking in children with DS and typically developing peers.

Materials and Methods

The study was carried out in accordance with the principles of the Declaration of Helsinki, with the approval of the Research Ethics Committee (approvel number, 2018/1582) and necessary permissions from the relevant institutions. A total of one hundred children aged 2-6 years, 50 with DS (who applied to four special education centers) and 50 with normal development (kindergarten children), were taken as the study sample. There was no developmental anomaly in the lower extremities of the children included in both groups. The parents of the children were informed and their written consent was obtained. Age and independent walking age were learned from parents. Measurements, data recordings and evaluations were made by the same physiotherapist. Measurements were repeated at least twice and the averages were recorded.

Initally, the children's height (cm) and weight (kg) were measured in light clothes and without shoes. Then, in the supine position, the Q angle was measured using a standard goniometer. Anterior superior iliac spine, midpoint of the patella and tibial tuberosity were marked for this measurement. The Q angle was determined and recorded in degrees by aligning the midpoint of the goniometer to the midpoint of the patella, one arm to the anterior superior iliac spine point, and the other arm to the tibial tuberosity point (20).

Pes planus was evaluated in the standing position. For this evaluation, a footprint was first obtained using a foot imprinter. The foot imprinter consists of a rigid platform and a plastic-coated mat on both sides. The front surface of the mat on which the foot will be stepped on is supported by rubber from the bottom. The back surface, impregnated with stamp ink, is the side facing the platform where the footprinted paper will be placed. For obtaining the footprint, a sheet of paper was placed on the rigid platform and the ink-impregnated surface was covered over the paper. With the aid of a physiotherapist, the child was stepped the foot to be studied on the rubber layer, with contralateral foot out of the platform. The process was also repeated for the other foot. During the procedure, the researcher controlled the foot position on the platform to prevent the foot from slipping (21).

Later, BMI and Staheli index (SI) were calculated. Using growth curves created for children (22), corresponding percentiles were determined for body weight, height, and BMI data. Body mass index (BMI) was calculated by dividing body weight by the square of the body height (kg/cm2). In the footprint, the length of the narrowest part of the midfoot (A) and the length of the widest part of the heel (B) were measured in mm. Staheli index was obtained by dividing the A value by the B value (SI:A/B). If the SI>1, it was considered pes planus (21,23).

Analysis of Data

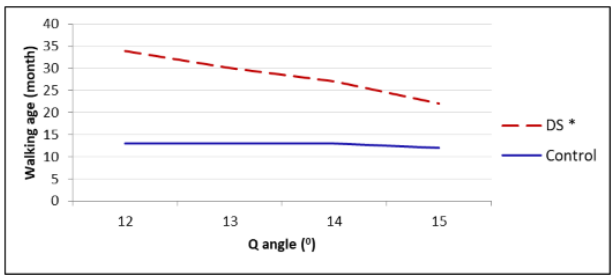
The obtained data for this study were evaluated by SPSS 21.0 (Statistical Package for Social Sciences). The subjects' age, weight, lenght, BMI, Q angle and SI were as the mean and standart deviation. Statistically analysis were using the Mixed model according to sex and age. Twelve-month groups were formed between the ages of 2 and 6 years to detect age-related changes (24-35 months, 36-47 months, 48-59 months, 60-72 months). Means and differences between means were determined by t test and Chi-Square test. The relationship between the parameters was investigated with the Pearson Coorrelation test. In all tests, $p<0.05$ was considered statistically significant.

Results

The study included 50 children with DS (26 boys, 24 girls) and 50 typically developing children (control) (24 boys, 26 girls) aged 2-6 years. Thirty-six (72%) children with DS were able to walk independently, and the mean walking age was 26±8 months (boys 28±1 months; girls 25±1 months). All of the children in control group could walk independently and the mean walking age was 12±2 months (boys 13±2 months; girls 12±1 months). It was determined that the walking age of children with

DS was statistically significantly (p<0.0001) delayed compared to the children in the control group. In addition, it was observed that this delay was statistically significant (p<0.05) more in boys with DS than in girls. While the mean height of children with DS was shorter than the children in control group in all age groups, it was observed that mean body weight was lower at 24-35 months, similar at 36-59 months, and higher at 60-72 months (Table 1). The distribution and percentile values of BMI by age group and gender are shown in Table 2. BMI in girls with DS was found to be at the upper limit of normal weight (85%) in all age groups. In boys with DS, an increase in BMI was observed with age. Although BMI was generally higher in girls with DS, the difference was not statistically significant (p>0.05). There was no significant relationship between BMI and walking age (p>0.05; r, -0.036).

In all age groups, independent of DS, Q angle values were higher in girls, but the difference was not statistically significant (p>0.05). Even though there was no difference between the right and left side Q angle values, there was a strong correlation between the two sides' angles (p<0.0001; r, 0.98)(Table 3). In addition, no significant relationship was found between Q angle and walking age (p>0.05; r, -0.32). However, as the Q angle value increased, the difference in walking age between the two groups decreased statistically (p<0.001) (Figure 1).



* p<0.001

Figure 1. The effect of the Q angle (0) on the difference between the walking onset age of children with Down syndrome (DS) and children in the control group

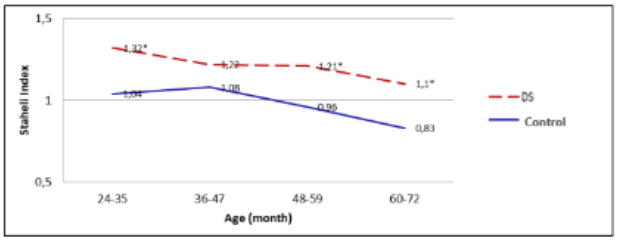


Figure 2. Comparison of Staheli index by age and Down syndyome (DS)

The SI calculated from the footprints of the children was found to be statistically significantly higher in the right foot (DS group, 1.17±0.28; control group, 0.94±0.04) and left foot (DS group, 1.11±0.27; control group, 0.93±0.06) of the children with DS, regardless of age and gender (p<0.001). According to age groups, SI>1 was observed in both groups at 24-47 months, while SI values were higher in children with DS and SI>1 continued until the 72nd month in children with DS. There was no difference between the SI values of the right and left sides, as well as a strong relationship was detected between the two sides (p<0.0001; r, 0.72) (Table 4)(Figure 2). SI>1 before the age of 4 was considered physiological. However, SI>1 persisting until 6 years of age in children with DS was accepted as pes planus. No statistically significant correlation was observed between the SI preferred to evaluate the presence and degree of pes planus and the walking age (p>0.05; r, 0.11).

Table 1. Comparison of Bodyweight, Height and Percentile (%) Values According to Age in Children with DS and Control Group

Age	Weight (kg)				Height (cm)			
(Month)	DS		Control		DS		Control	
24-35	10.2±2.2*	3%	12.5±1.9	25%	80.8±6.1*	3%	91±5.2	50%
36-47	14.8±2.5	25%	14.2±2.9	25%	93.7±4.7*	10%	96.4±5.4	25%
48-59	16.3±2.4	25%	16.2±2.5	25%	98.5±3.1*	3%	102.6±6.6	25%
60-72	22.5±4.1*	75%	19.3±1	50%	107±3.1*	10%	109±1.5	25%

*, p<0.05

Table 2. Distribution of BMI (kg/m2) of Children with DS and Control Group by Age and Gender (mean±standard deviation)

Age		DS			Control		
(Month)	Gender	n	BMI	PV	n	BMI	PV
24-35	Boy	4	14.82±2.07	15%	6	15.95±2.67	50%
	Girl	7	17.30±2.75	85%	5	18.90±2.80	95%
36-47	Boy	8	16.73±1.93	75%	6	16.78±0.98	75%
	Girl	4	17.55±1.68	85%	8	15.93±2.74	50%
48-59	Boy	4	16.95±0.51	75%	5	15.21±1.46	25%
	Girl	3	17.11±2.24	85%	5	15.46±1.18	50%
60-72	Boy	10	20.38±1.40	95% +	7	15.88±0.96	50%
	Girl	10	17.89±2.34	85%	8	15.69±1.42	50%

n: number of cases, PV: percentile value

Table 3. Comparison of Q Angle (0) Values by Age, Gender and Side (mean±standard deviation; n, number of cases)

Age (Month)	Gender	Q° DS n	DS Right	DS Left	Control n	Control Right	Control Left
24-35	Boy	4	13.05±1.17	13.13±1.09[a,b]	6	12.98±1.46	12.90±1.37[a,b]
	Girl	7	14.86±0.87	14.96±0.77[a,b]	5	14.66±1.11	14.66±1.11[a,b]
36-47	Boy	8	12.43±0.86	12.40±0.67[a,b]	6	12.60±0.37	12.77±0.26[a,b]
	Girl	4	13.93±0.83	13.93±0.83[a,b]	8	14.31±1.24	14.40±1.24[a,b]
48-59	Boy	4	13.18±0.78	13.25±0.74[a,b]	5	13.06±1.14	13.06±1.14[a,b]
	Girl	3	14.93±1.10	15.10±1.51[a,b]	5	14.42±0.54	14.32±0.66[a,b]
60-72	Boy	10	12.54±0.78	12.59±0.80[a,b]	7	13.01±0.63	13.16±0.54[a,b]
	Girl	10	14.48±0.95	14.48±0.95[a,b]	8	14.83±0.82	14.76±0.98[a,b]

a: p<0.0001, b: r=0.90-0.98

Table 4. Comparison of Staheli Index by age, gender and side (mean±standard deviation; n, number of cases)

Age (Month)	Staheli Index DS Gender	DS n	DS Right	DS Left	Control Gender	Control n	Control Right	Control Left
24-35	Boy	4	1.30±0.17*	1.29±0.10*[a,b]	Boy	6	1.05±0.17	1.03±0.06[a,b]
	Girl	7	1.36±0.17*	1.38±0.20*[a,b]	Girl	5	1.05±0.22	1.03±0.24[a,b]
36-47	Boy	8	1.28±0.31*	1.29±0.16[a,b]	Boy	6	1.19±0.11	1.17±0.15[a,b]
	Girl	4	1.30±0.25*	1.33±0.27*[a,b]	Girl	8	1.11±0.39	1.01±0.25[a,b]
48-59	Boy	4	1.18±0.31*	1.19±0.23*[a,b]	Boy	5	0.98±0.13	1.04±0.09[a,b]
	Girl	3	1.27±0.24*	1.24±0.17*[a,b]	Girl	5	0.93±0.29	0.90±0.25[a,b]
60-72	Boy	10	1.08±0.28*	1.05±0.29*[a,b]	Boy	7	0.82±0.22	0.77±0.23[a,b]
	Girl	10	1.14±0.31*	1.01±0.26*[a,b]	Girl	8	0.86±0.21	0.89±0.17[a,b]

DS: Down Syndrome, *: p<0.001, a: p<0.0001, b: r=0.72

Discussion

Growth, heart, thyroid, vision and hearing screenings required for monitoring the health status of children with DS are clearly defined in medical guidelines. Regarding the evaluation and management of the musculoskeletal system in these children, there are inconsistent and variable recommendations due to the lack of data, and the focus is usually cervical spine problems (11). The neuropsychological profile defined for children with DS is closely related to motor development. Studies supporting this knowledge have also shown that motor development is strongly associated with both cognitive and language development (24,25). One of the indicators of motor development is the ability to walk independently. In this study, the possible effects of BMI, Q angle and the presence of pes planus on the reported delay in walking age in children with DS were investigated.

It has been reported that the walking age in children with DS is later than those of normally developing children (average 26-30 months), and the male gender affects the delay in walking age more (10,11,25,26). Similar to the literature, in our study, it was determined that the age of walking was statistically delayed (p<0.0001) in children with DS (DS group, 26±8 months; control group, 12±2 months). This delay was more statistically significant (p<0.0001) in boys (boys 28±1 months; girls 25±1 months). No relationship was observed between gender and walking age in children the control group.

Body weight, height and BMI are basic elements in assessing growth, which is an excellent indicator of health status. Using the data of these parameters, the researchers have obtained growth curves that are very helpful in the routine monitoring of growth in children. Growth curves were created not only for healthy children but also for children with DS (7,22,27-29). Short height is the characteristic feature of DS, showing distinct individual differences depending on comorbidities and hereditary factors (7,28,29). Body weight begins to increase in late infancy in DS children and evolves into overweight and obesity over time (8,9). Body weight, height and BMI values obtained in this study were compared with percentile values defined for healthy children (22). It was found that height in DS children was lower in the percentile (3-10%) than healthy children in all age groups, and body weight increased with age (3%-25%-75%, respectively). The increase in body weight with increasing age and the persistence of short height in children with DS caused increased BMI. The mean BMI was found to be 75-85 percentile in children with DS and 50 percentile in children the control group. Short height in children with DS was independent of age and gender. There was no significant relationship between BMI and walking age.

The Q angle, first described by Brattström (30), can be measured in the supine position (traditional) and standing, as well as calculated on images (plain

radiographs, magnetic resonance images, computed tomography)(13). The results of the studies in which the Q angle was measured in healthy individuals, students, athletes and patients with gonarthrosis are accessed from databases (14-18, 31,32). However, a study in which the Q angle, which is known to be associated with patellofemoral pain and instability, was measured in children with DS has not been found in the literature. In this study, besides other parameters, the effect of Q angle on the age of walking in DS children was investigated. Since it is not possible for all children to stand up and it would be unethical for them to receive radiation for the study, our Q angle measurements were made with the traditional method in the supine position.

In some studies, it has been reported that the Q angle is higher in female than in male, and higher on the right side than on the left side in the young and adult population (14,17,18,31). Q angle over 150or male and over 200for female is considered pathological. Rauh et al. (18), on the other hand, found that runners with a Q angle of more than 20° were 1.7 times more likely to be injured, and if the difference between the right and left Q angles were greater than 4°, the risk of injury was 1.8 times higher. While Mandigo and Livingston (32) said that Q angle was affected by dominance, Jaiyesimi and Jedede (14) found that higher right Q angle was independent of leg dominance. Cankaya et al. (16) reported that in healthy children aged 2–8, the Q angle decreases with age (mean 140 to 120), and the angular value is not dependent on factors such as gender, pes planus, and measurement position. In this study, independent of DS, Q angle values were higher in girls in all age groups, but the difference was not statistically significant ($p>0.05$). There was also no significant difference between the right and left Q angles. Contrary to the results of Cankaya et al. (16), no significant decrease in Q angle was observed with increasing age in children with DS and control group. There was no statistically significant relationship between Q angle and DS, pes planus and walking age ($p>0.05$). Whereas, as the Q angle value increased, the difference between the walking age of children with DS and control group decreased ($p<0.05$).

Pes planus (flat feet), defined by the loss of the medial longitudinal arch where the foot touches or nearly touches the ground, is common among young children and is usually asymptomatic. This congenital condition typically improves with age as the foot muscles become stronger or may persist in older children and adults (33-36). The medial longitudinal arches of boys mature 1 year later than girls (36). The relationship between overweight and obesity in children and flat feet is known (36,37). Children with asymptomatic flat-footed are followed with the recommendation to maintain a healthy weight, treatment up to surgical intervention may be required for resistant symptomatic pediatric pes planus (painful and/or stiff) (33). Pes planus can be identified by footprints, heel-to-arch ratio, subjective evaluation, and radiographic measurements (12,21,23,38). Despite all these known facts, there is no generally accepted classification system or definition of pediatric flatfoot (38).

In a study of kindergarten children aged 3 to 6 years, it is mentioned that there is an average of 44% pes planus in all children, and the prevalence decreases from 54 to 24 from 3 to 6 years of age (36). It has been reported that the prevalence of pes planus in DS is 60-88%, even almost universal (91%) (11,12,39). In the accessible literature, there is no study investigating the relationship between the presence of pes planus and walking age in children with DS. In our study, in which the aforementioned relationship was investigated, a low-cost, radiation-free and simple measurement method was preferred for the detection of pes planus. Footprints could not be taken in 2% of the children with DS who participated in the study because they could not stand. The SI was >1 in 74% of children with DS and 60% of children the control group. While SI decreased after 4 years of age in children the control group, values above 1 continued in children with DS. There was no significant difference in SI values according to gender ($p>0.05$). In this study, in which only the presence of pes planus was evaluated without distinguishing its degree and etiology, no significant relationship was found between pes planus and walking age in children with DS. There was no significant relationship between pes planus and BMI in children with DS and the control group ($p>0.05$).

Conclusion

Parents of children with DS are concerned about how delayed their child's walking age will be. According to the results of this study, the following recommendations can be made to parents and physiotherapists of children with DS who do not have serious additional health problems to reduce the delay in walking age and to prevent the ignored physiological pes planus from becoming rigid:

- To regulate the nutrition programs of children with DS, who are expected to be shorter than the general population, and to keep the BMI within healthy limits by controlling their weight gain.

- Regular exercise of the quadriceps muscle in an assisted and controlled manner, in addition to other physical therapy procedures.

- To carefully evaluate the presence of pes planus in all children with DS, to provide the right shoe selection and to give detailed information about the importance of foot health.

Sources of Support: None.

Conflict of Interest: There is no conflict of interest.

Ethical Approval: The ethical approval of the study was gathered from the Ethical Committee for Non-

Pharmaceutical and Non-Medical Device Researches of the Necmettin Erbakan University (Approval Date: 16.11.2018, Approval Number: 2018/1582).

Informed Consent: Since this study was conducted in children, consent was obtained from the parents.

Author Contributions:

Concept-GE, IIU; Design-GE, IIU; Supervision-GE, IIU; Resources and Financial Support-GE, IIU; Materials-GE; Data Collection and/ or Processing-GE, IIU, MSI; Analysis and/or Interpretation-MSI, IIU; Literature Research-GE, IIU; Writing Manuscript-IIU, GE; Critical Review-GE, IIU, MSI.

Acknowledgments:

Part of this research was presented as an oral presentation at the XX. National Congress of Anatomy.

References

1. Wang HY, Long IM, Liu MF. Relationships between task-oriented postural control and motor ability in children and adolescents with Down syndrome. Research in Developmental Disabilities. 2012;33(6):1792-8.

2. Galli M, Rigoldi C, Brunner R, Virji-Babul N, Giorgio A. Joint stiffness and gait pattern evaluation in children with Down syndrome. Gait Posture. 2008;28(3):502-6.

3. Boontan N, Rojnueangnit K. Growth patterns of Thai children with Down Syndrome from birth to 5 years. J Pediatr Genet. 2021;10(1):16-22.

4. Bull MJ. Down Syndrome. N Engl J Med. 2020;382(24):2344-52.

5. Rigoldi C, Galli M, Albertini G. Gait development during lifespan in subjects with Down syndrome. Res Dev Disabil. 2011;32(1):158-63.

6. Carmeli E, Ariav C, Bar-Yossef T, Levy R, Imam B. Movement skills of younger versus older adults with and without Down syndrome. Res Dev Disabil. 2012;33(1):165-71.

7. Tüysüz B, Topal Göknar N, Oztürk B. Growth charts of Turkish children with Down syndrome. Am J Med Genet A. 2012;158A(11):2656-64.

8. Bertapelli F, Pitetti K, Agiovlasitis S, Guerra-Junior G. Overweight and obesity in children and adolescents with Down syndrome-prevalence, determinants, consequences, and interventions: a literature review. Res Dev Disabil. 2016;57:181-92.

9. Bindayel IA. Relationship between Down syndrome (DS) and obesity in children and adolescents and its relation to dietary and lifestyle factors. Progress in Nutrition. 2021;23(4): e2021180.

10. Tudella E, Pereira K, Basso RP, Savelsbergh GJP. Description of the motor development of 3–12 month old infants with Down syndrome: the influence of the postural body position. Res Dev Disabil 2011;32:1514–20.

11. Foley C, Killeen OG. Musculoskeletal anomalies in children with Down syndrome: an observational study. Arch Dis Child. 2019;104(5):482-7.

12. Kanai Y, Mutsuzaki H, Watanabe M, et al. Use of malleoli as an indicator for flatfoot in patients with Down syndrome: development of a simple and non-invasive evaluation method through medial longitudinal arch. J Phys Ther Sci. 2020;32(5):315-8.

13. Smith TO, Hunt NJ, Donell ST. The reliability and validity of the Q-angle: a systematic review. Knee Surg Sports Traumatol Arthrosc. 2008;16(12):1068-79.

14. Jaiyesimi AO, Jegede OO. Influence of gender and leg dominance on Q-angle among Adult Nigerians. Afr J Phys and Reh Sci. 2009;1:18−23.

15. Park SK, Stefanyshyn DJ. Greater Q angle may not be a risk factor of patellofemoral pain syndrome. Clin Biomech. 2011;26(4):392-6.

16. Cankaya T, Dursun Ö, Davazlı B, et al. Assessment of quadriceps angle in children aged between 2 and 8 years. Turk Pediatri Ars. 2020;55(2):124-30.

17. Havaslı F, Demir M, Ciçek M, Yoldas A. Association between Q angle and predisposition to gonarthrosis*. Anatomy 2017;11(1):21–25.

18. Rauh MJ, Koepsell TD, Rivara FP, Rıce SG, Margherita AJ. Quadriceps angle and risk of injury among high school cross-country runners. J Orthop Sports Phys Ther. 2007;37(12):725-33.

19. Antinolfi P, Bartoli M, Placella G, et al. Acute patellofemoral instability in children and adolescents. Joints. 2016;4(1):47–51.

20. Jimshad TU, Mainali S, Swethankh KS, John AT. Does Q angle change in spastic diplegia children? Indian J Pediatr 2016; 2: 85−9.

21. Hernandez AJ, Kimura LK, Laraya MHF, Favaro E. Calculation of staheli's plantar arch index and prevalence of flat feet: a study with 100 children aged 5-9 years. Acta Ortopédica Bras. 2007;2:68-71.

22. Neyzi O, Bundak R, Gokcay G, et al. Reference Values for Weight, Height, Head Circumference, and Body Mass Index in Turkish Children. J Clin Res Pediatr Endocrinol. 2015;7(4):280-93.

23. Staheli LT, Chew DE, Corbett M. The longitudinal arch. A survey of eight hundred and eighty-two feet in normal children and adults. J Bone Joint Surg Am. 1987;69(3):426-8.

24. Vicari S. Motor development and neuropsychological patterns in persons with Down syndrome. Behavior Genetics. 2006;36(3):355-64.

25. Yamauchi Y, Aoki S, Koike J, Hanzawa N, Hashimoto K. Motor and cognitive development of children with Down syndrome: The effect of acquisition of walking skills on their cognitive and language abilities. Brain Dev. 2019;41(4):320-6.

26. Corrado B, Sommella N, Ciardi G, et al. Can early physical therapy positively affect the onset of independent walking in infants with Down syndrome? A retrospective cohort study. Minerva Pediatr. 2022;74(1):31-9.

27. Cronk C, Crocker AC, Pueschel SM, et al. Growth charts for children with Down syndrome: 1 month to 18 years. Pediatrics. 1988;81:102-10.

28. Myrelid A, Gustafsson J, Ollars B, Anneren G. Growth charts for Down's syndrome from birth to 18 years of age. Arch Dis Child. 2002;87:97-103.

29. Meguid NA, El-Kotoury AI, Abdel-Salam GM, El-Ruby MO, Afif HH. Growth charts of Egyptian children with Down syndrome (0–36 months). East Mediterr Health J. 2004;10:106–15.

30. Brattström H. Shape of the intercondylar groove normally and in recurrent dislocation of the patella. Acta Orthop Scand 1964;68:1-44.

31. Woodland LH, Francis RS. Parameters and comparisons of the quadriceps angle of collage-aged men and women in the supine and standing positions. Am J Sports Med. 1992; 20(2):208-211.

32. Mandigo JL, Livingston LA. Bilateral Q angle symetry and anterior knee pain syndrome. Clinical Biomechanics. 1999;14(1):7-13.

33. Ford SE, Scannell BP. Pediatric flatfoot: pearls and pitfalls. Foot Ankle Clin. 2017; 22(3):643–56.

34. Michaudet C, Edenfield KM, Nicolette GW, Carek PJ. Foot and ankle conditions: pes planus. FP Essent. 2018;465:18-23.

35. Carr 2nd CB, Yang S, Lather LA. Pediatric pes planus: A state of the art review. Pediatrics. 2016;137(3):e20151230.

36. Pfeiffer M, Kotz R, Ledl T, Hauser G, Sluga M. Prevalence of flat foot in preschool-aged children. Pediatrics. 2006;118:634-9.

37. Bordin D, De Giorgi G, Rigon F. Flat and cavus foot, indexes of obesity and overweight in a population of primary-school children. Minerva Pediatr. 2001;53(1):7-13.

38. Pereira K, Basso RP, Lindquist AR, da Silva LGP, Tudella E. Infants with Down syndrome: percentage and age for acquisition of gross motor skills. Res Dev Disabil. 2013;34(3):894-901.

39. Concolino D, Pasquzzi A, Capalbo G, Sinopoli S, Strisciuglio P. Early detection of podiatric anomalies in children with Down syndrome. Acta Paediatr. 2006;95(1):17-20.