JBACHS
Journal of Basic and Clinical Health Sciences

J Basic Clin Health Sci 2025: 9; 85-91
https://doi.org/10.30621/jbachs.1513965
RESEARCH ARTICLE

THE RELATIONSHIP BETWEEN BODY MASS INDEX AND GAIT CHARACTERISTICS AND GAIT PERFORMANCE OF CHILDREN WITH DUCHENNE MUSCULAR DYSTROPHY

Güllü Aydın-Yağcıoğlu[1], Numan Bulut[2], İpek Alemdaroğlu-Gürbüz[2], Öznur Tunca[2]

[1] University of Health Sciences, Gülhane Faculty of Health Sciences, Department of Orthotics and Prosthetics, Ankara, Turkey
[2] Hacettepe University, Faculty of Physical Therapy and Rehabilitation, Ankara, Turkey

ORCID: G.A.Y. 0000-0003-1658-7697; N.B. 0000-0001-5427-1103; I.A.G. 0000-0001-5556-6608; O.Y. 0000-0002-0855-9541

Corresponding author: Güllü Aydın-Yağcıoğlu, **E-mail:** gulluaydin23@gmail.com
Received: 10.07.2024; **Accepted:** 12.01.2025; **Available Online Date:** 31.01.2025

Cite this article as: Aydın-Yağcıoğlu G, Bulut N, Alemdaroğlu-Gürbüz İ, Tunca Ö. The Relationship Between Body Mass Index and Gait Characteristics and Gait Performance of Children with Duchenne Muscular Dystrophy. J Basic Clin Health Sci 2025; 9: 85-91.

ABSTRACT

Purpose: Obesity is a common problem in Duchenne Muscular Dystrophy (DMD) and adversely affects disease progression. This study aimed to investigate the relation between Body Mass Index (BMI) and gait characteristics and gait performance in patients with DMD.
Material and Methods: Weight and height were measured to calculate BMI. BMI z-scores were used to categorise weight. Height, weight, and BMI were standardised to sex- and age-corrected z-scores based on the Turkish population. The gait characteristics were evaluated with the Gait Assessment Scale for Duchenne Muscular Dystrophy (DMD-GAS) and Quality and Independence of Gait Classification Scale for Duchenne Muscular Dystrophy (QIGS-DMD). The gait performance was assessed by the 6-minute walk test and the 10-meter walk/run test. The correlation between body composition and gait parameters was analysed.
Results: Eighty-six children with DMD were included in the study. Among the participants, 40.7% had a BMI above the normal range. There were moderate correlations between DMD-GAS and height, weight, and BMI and moderate correlations between QIGS-DMD and height, weight, and BMI ($p<0.01$).
Conclusion: The current findings revealed that an increase in BMI affects the characteristics, quality, and independence of gait in children with DMD, highlighting the need for regular monitoring and timely intervention.

Keywords: Duchenne Muscular Dystrophy, obesity, body mass index, gait, gait analysis

INTRODUCTION

Duchenne muscular dystrophy (DMD) is a devastating childhood disease with an X-linked recessive inheritance (1). Proximal muscle weakness, joint contractures, gait abnormalities and postural disorders are common characteristics of the disease in ambulatory period which limit functional abilities (1, 2). Progressive muscle weakness and joint contractures result in distinctive gait which is characterized by increased lumbar lordosis and base of support, decreased stride length and gait speed, and toe walking as a compensatory mechanism (3-5). Gait abnormalities including gait performance and characteristics, like other associated symptoms of the disease, become more severe as the disease progresses (6, 7). Children with this condition usually lose the ability to walk in their teens and become wheelchair-dependent (2).

Table 1. Descriptive characteristics of the study population (n=86)

	Mean (SD)	Min – Max
Age (month)	107.90 (26.53)	60 – 175
Height (cm)	126.25 (13.12)	103 – 161
Weight (kg)	30.77 (10.58)	17 – 68
BMI (kg/m^2)	18.80 (3.13)	13.08 – 28.80
Height Z-score	-0.85 (1.41)	-3.99 – 2.71
Weight Z-score	0.17 (1.06)	-2.23 – 2.68
BMI Z-score	0.72 (0.98)	-1.98 – 2.63
Height percentile	30.32 (31.51)	0 – 99.66
Weight percentile	54.57 (30.02)	1 – 100
BMI percentile	70.72 (27.03)	2 – 100
	N	**%**
BMI Percentile		
• ⩽5th	1	1.2
• >5th and <85th	50	58.1
• ⩾85th and <95th	19	22.1
• ⩾95th	16	18.6
Steroid usage		
• Yes	77	89.5
• No	9	10.5

BMI: body mass index; SD: Standard deviation

In addition to physical impairments, nutritional disorders are also among the frequently observed symptoms in children with DMD. Willig et al found that the highest prevalence of obesity (54%) occurs around the age of 13; and undernutrition occurs after the age of 14, with a similar prevalence of underweight at the age of 18 (8). The results of a study conducted in France by Martigne et al. that 73% of children were classified as obese by the age of 13, while 34% were underweight and 47% were obese by the age of 18 in a DMD population (9). A study conducted by Davidson et al. in an Australian DMD population reported that children with DMD aged 3-12 years had a higher body mass index (BMI) than typically developing children, and that steroid users had a higher BMI than non-steroid users (10). Additionally, the literature reported that steroid treatment, a common medical intervention for DMD (11), had a detrimental impact on BMI (12). Once BMI increases, it negatively affects sleep quality, physical and lung functions, and increases metabolic risk factors in children with DMD (13-16).

As previously stated, obesity is prevalent among these children, and emerging evidence indicates that obesity has a negative impact on the progression of disease. However, to the best of our knowledge, no studies have examined the impact of obesity on gait in DMD. Investigating the effect of differences in BMI on gait in children with DMD may be a step towards filling the gap in this area. Thus, it was planned to investigate the relationships between BMI and gait characteristics and performance in a Turkish DMD cohort.

MATERIAL AND METHODS

Participants

This study was conducted at the Department of Physiotherapy and Rehabilitation between November 2022 and November 2023. The study included 86 children with DMD diagnosed through genetic testing or muscle biopsy. The inclusion criteria were as follows: a diagnosis of DMD, an age of at least five years, and the ability to walk at least 10 meters independently (17, 18). Individuals with a history of lower extremity surgery or trauma within the previous six months, as well as those who were unable to comply with the physiotherapists' instructions, were excluded from the study. The children and their parents signed the informed consent form. Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of the Hacettepe University (Date: 01.11.2022, Decision no: 2022/18-23). The study adheres to the mandates of the Declaration of Helsinki.

Assessments

All assessments performed in the study were performed by physiotherapists with at least 6 years of

Table 2. The gait characteristics and gait performance test results of the children (n=86)

Variables	Mean (SD)	Min – Max
DMD-GAS (0-20)	11.98 (4.93)	1 – 20
6MWT (m)	384.52 (93.89)	111 – 568
10MWT (sec)	8.47 (2.06)	5.55 – 16.46
	N	**%**
QIGS-DMD		
√ Level-1	8	9.3
√ Level-2	44	51.2
√ Level-3	34	39.5

DMD-GAS: Gait Assessment Scale for Duchenne Muscular Dystrophy; 6MWT: 6-minute walk test; 10MWT: 10-meter walk/run test; QIGS-DMD: Quality and Independence of Gait Classification Scale for Duchenne Muscular Dystrophy; SD: standard deviation

experience in DMD management and assessments. All tests were also performed in a quiet room to minimize potential distractions for the children during their routine follow-up visits.

Body Mass Index

The children's height was measured using a portable stadiometer and weight was measured using a bascule. Children's height, weight and BMI were standardized as sex- and age-adjusted z-scores based on the Turkish population (19). Using the criteria defined by the World Health Organisation (WHO), BMI Z-scores by age are graded as follows (20): Normal = > -1 to < +1 SD; overweight= > +1SD; Obesity= > +2SD; Thinness= < -2SD; Severe Thinness= < -3SD. BMI percentiles were also expressed as follows: ⩽5th percentile= underweight; >5th and <85th percentile= normal weight; ⩾85th and <95th percentile= overweight; ⩾95th percentile= obese (9).

Gait Assessments

The gait characteristics were evaluated by the Gait Assessment Scale for Duchenne Muscular Dystrophy (DMD-GAS) and the Quality and Independence of Gait Classification Scale for Duchenne Muscular Dystrophy (QIGS-DMD). These scales were developed specifically for DMD and found valid and reliable [(ICC>0.90), and (K>0.80), respectively] (18, 21). The 10 item DMD-GAS evaluates the compensatory movements of body parts such as the foot, knee, hip, and trunk during walking and the time-distance characteristics of gait, such as speed, stride length, and base of support in children with DMD. Scores ranged between 0 and 20 which lower scores indicated impaired gait characteristics (18). The QIGS-DMD classifies the independence and quality of gait in 5 levels. Level 5 indicates that child has lost the ability to walk, while level 1 indicates that child is able to walk independently without compensation (21).

The gait performance was evaluated by using the 6-minute walk test (6MWT) and the 10-meter walk/run test, which were valid and reliable measures in DMD. The 6MWT is considered as the primary endpoint in clinical trials with DMD populations. The distance taken during the 6MWT were recorded in meters (22, 23). The 10MWT is another outcome measure used in studies with DMD populations. The time taken during walking a 10 meter walkway was recorded in seconds (22).

Data Analysis

IBM SPSS Statistics software version 26.0 was used for data analysis. Descriptive characteristics were defined by mean and standard deviation (mean±SD) for quantitative data and number/percentages for qualitative data. After verifying the absence of a standard statistical normal distribution using the Kolmogorov-Smirnov test, Spearman's correlation coefficient was used to assess the relation between body composition and gait data of the children. The strength of the correlations (r) was graded as: 0.05 to 0.30 weak; 0.30 to 0.70 moderate; and 0.70 to 1.00 strong (24, 25). Chi-square test was used to compare gait quality and independence by BMI percentile. Statistical significance was set at a p<0.05.

G* Power (Version 3.1.9 Universität Düsseldorf, Düsseldorf, Germany) was used for post-hoc power analysis. Taking into account the relationship between BMI and DMD-GAS in the current study, the

Table 3. The correlations between the gait characteristics and gait performance of the children and body composition (Spearmen's *r*)

Gait Assessments	Height	Weight	BMI	Height Z-score	Weight Z-score	BMI Z-score	BMI percentile
DMD-GAS	**-0.36****	**-0.44****	**-0.36****	0.07	-0.06	-0.10	-0.10
QIGS-DMD	**0.44****	**0.48****	**0.35****	-0.07	0.06	0.07	0.08
6MWT	-0.05	-0.12	-0.15	0.10	0.04	-0.02	-0.02
10MWT	-0.01	0.07	0.15	-0.16	-0.06	0.06	0.06

*** p<0.01*

effect size of the current study was 0.36 and the post-hoc power was 91.8%.

RESULTS

The results related to the descriptive characteristics of children were shown in Table 1. According to BMI percentile, a total of 40.7% of the cohort had a BMI above the normal range in which 22.1% were overweight and 18.6% were obese.

The results related to the gait characteristics and gait performance of the children were given in Table 2.

There were moderate correlations between DMD-GAS and height, weight, and BMI (r=-0.36, r=-0.44, r=-0.36, respectively) and moderate correlations between QIGS-DMD and height, weight, and BMI (r:0.43, r:0.48, r:0.35, respectively) ($p<0.01$). The findings related to the correlations of the test parameters were shown in Table 3.

Statistical differences were found in the comparison of gait quality and independence by BMI percentile ($p<0.05$) (Figure 1).

DISCUSSION

Prenatal, genetic, developmental and psychosocial risk factors are important determinants of susceptibility to obesity. Reduced energy expenditure due to limited physical activity and mobility and steroid use leads to increased risk of obesity in individuals with DMD (26). Excessive weight gain worsens many functional and daily life factors in children with DMD. Previous studies have shown that higher BMI and fat mass contribute to clinical milestones, metabolic risk factors, and respiratory function in children with DMD (13, 14, 16, 27, 28). In this study which was aimed to investigate the relations between excessive weight gain and gait characteristics showed that a significant proportion of the cohort were overweight or obese, and the increased weight and higher BMI might contribute to the deterioration of gait characteristics including gait performance and quality.

Considering the BMI analysis of our study, it can be interpreted that the obesity rate of the cohort is approximately similar to the rate in different countries which highlights the vulnerability of DMD population to obesity (8-10, 29). The Z-scores of the studied population showed that this cohort included both thin and obese children. It has been reported in the literature that younger children with DMD are at risk of obesity, whereas older children with DMD are at risk of underweight due to muscle damage, nutritional problems and dysphagia (10, 14). With these results, it can be stated that the body composition characteristics of the population in this study which included a wide age range by including children up to 14.5 years of age, are compatible with the literature (8-10, 29).

As indicated in several studies, obesity or overweight is a potential risk for gait characteristics in children with various musculoskeletal disorders or typical development (30-33). Hills et al. showed that the cadence, cycle duration, velocity, and stance duration of gait of obese children were worser than children with normal weight (30). Another study showed the negative effect of obesity on the stance duration of gait pattern in children with Down Syndrome (DS) (31). Similarly, Elshemy et al. reported that children with DS had a lower cadence and a shorter stride length than healthy children and non-obese children with DS (32). Obesity has also been reported as a contributor to the disability of children with Charcot-Marie-Tooth (33) and excessive weight was shown to be a potential risk for normal gait characteristics in children with cerebral palsy (34). Similar to the results of the studies above, the current study provided evidence that gait characteristics, gait quality and independency worsened as children's height, weight and BMI increased in DMD. Weight gain was related to the shorter stride length, increased trunk movement, arm swing, base of support, and lumbar lordosis, decreased gait speed, or adverse joint kinematics according to DMD-GAS. On the other

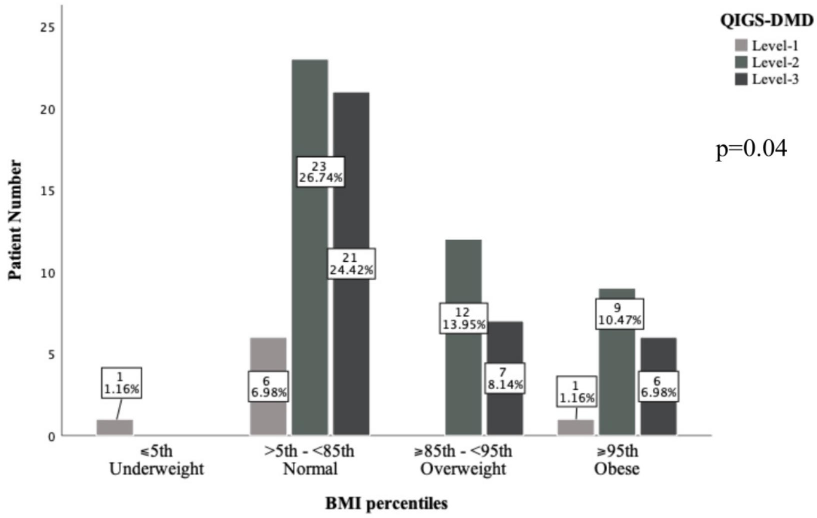

Figure 1. Distribution of QIGS-DMD levels according to the BMI percentile

hand, obesity is known to impair balance and constitutes a risk factor for falls (35). Thus, the authors hypothesized that children with DMD may have developed a strategy to maintain their balance by altering their gait characteristics. It can also be interpreted that overweight or obese children with DMD might use their muscles in a way that caused more compensatory movements and affecting gait characteristics more to maintain upright stability.

In addition to the common effects of obesity in DMD, there have also been reports of adverse effects on motor function (14, 36). A previous study showed that body composition and anthropometry were associated with the functional level measured by Gross Motor Function Classification System (GMFCS) in children with DMD (36). Billich et al. found that obesity increased the risk of fracture in younger DMD children, and that obesity at 8 years was associated with 10-m walk/run test results, but did not affect other physical functions [supine-to-stand and climbing four stairs, North Star Ambulatory Assessment (NSAA), 6MWT] and forced vital capacity. They also found that obesity in other age groups was not associated with 10-m walk/run scores (14). Similarly, in this study, there was no association between obesity and children’s performance tests (6MWT and 10-m walk/run). There are 2 hypotheses considered as a reason for this. First, the mean age of our cohort indicated the early-mid stage of the disease, and although BMI was known to be higher in children in this period (37), they might have more preserved muscle mass (38). This means that younger DMD children with more muscle mass may be able to maintain gait performance despite an increase in body composition by modifying their gait characteristics. Second, our cohort included children predominantly on steroids. Although it has been known that obesity is more common in steroid-treated children, it is also known that steroids protect muscle mass and functional ability (10, 39). Approximately 90% of the children in this study were on steroids, which might explain why the gait performance of the children was preserved despite the increased BMI.

This study had several limitations. First, the gait parameters could not have been assessed by an objective method. Second, since the BMI data alone might not be sufficient to further interpretation of the effects of obesity, the lack of muscle-fat ratio measurement can be considered as another limitation. Studies that eliminate these limitations may provide a better understanding of the effect of excessive weight gain on gait characteristics in this population. There is also a need for studies that include more patients, a homogeneous population of patients of similar age, and longitudinal studies.

CONCLUSION

It is concluded that weight control during the disease process is essential since there may be deterioration in gait function related to the change of body composition, especially by the excessive weight gain in children with DMD. As a recommendation, regular monitoring of the weight in each visit might lead to timely interventions to maintain gait ability of children with DMD.

Acknowledgements: None.

Author contribution: Conceptualization: Güllü Aydın-Yağcıoğlu and Öznur Tunca. Methodology: Güllü Aydın-Yağcıoğlu, İpek Alemdaroğlu-Gürbüz and Öznur Tunca. Data curation: Güllü Aydın-Yağcıoğlu and Numan Bulut. Investigation: Güllü Aydın-Yağcıoğlu, Numan Bulut, İpek Alemdaroğlu-Gürbüz, and Öznur Tunca. Formal analysis: Güllü Aydın-Yağcıoğlu and Numan Bulut. Supervision: İpek Alemdaroğlu-Gürbüz and Öznur Tunca. Writing—original draft: Güllü Aydın-Yağcıoğlu, Numan Bulut, İpek Alemdaroğlu-Gürbüz and Öznur Tunca. Writing—review and editing: Güllü Aydın-Yağcıoğlu, Numan Bulut, İpek Alemdaroğlu-Gürbüz and Öznur Tunca.

Conflict of interests: All authors declare no conflicts of interest in this study.

Ethical approval: Ethical approval was obtained from the Non-Interventional Clinical Research Ethics Committee of the Hacettepe University (Date: 01.11.2022, Decision no: 2022/18-23). The study adheres to the mandates of the Declaration of Helsinki.

Funding: This study received no external funding.

Peer-review: Externally peer-reviewed.

REFERENCES

1. Bushby K, Finkel R, Birnkrant DJ, Case LE, Clemens PR, Cripe L, et al. Diagnosis and management of Duchenne muscular dystrophy, part 1: diagnosis, and pharmacological and psychosocial management. Lancet Neurol 2010;9(1):77-93.
2. Emery AE, Muntoni F, Quinlivan R. Duchenne muscular dystrophy: Oxford Monographs on Medical G; 2015.
3. Aydın Yağcıoğlu G, Yılmaz Ö, Alemdaroğlu Gürbüz İ, Bulut N, Karaduman A, Özkal Ö, et al. Examination of the relationship between foot-body posture and balance and gait in Duchenne muscular dystrophy. Ir J Med Sci 2023;192(4): 1883-1888.
4. Doglio L, Pavan E, Pernigotti I, Petralia P, Frigo C, Minetti C. Early signs of gait deviation in Duchenne muscular dystrophy. Eur J Phys Rehabil Med 2011;47(4):587-94.
5. Sutherland DH, Olshen R, Cooper L, Wyatt M, Leach J, Mubarak S, et al. The pathomechanics of gait in Duchenne muscular dystrophy. Dev Med Child Neurol 1981;23(1):3-22.
6. Hsu JD, Furumasu J. Gait and posture changes in the Duchenne muscular dystrophy child. Clin Orthop Rel Res 1993;288:122-5.
7. Sienko Thomas S, Buckon CE, Nicorici A, Bagley A, McDonald CM, Sussman MD. Classification of the gait patterns of boys with Duchenne muscular dystrophy and their relationship to function. J Child Neurol. 2010;25(9):1103-9.
8. Willig TN, Carlier L, Legrand M, Riviere H, Navarro J. Nutritional assessment in Duchenne muscular dystrophy. Dev Med Child Neurol 1993;35(12):1074-82.
9. Martigne L, Salleron J, Mayer M, Cuisset J-M, Carpentier A, Neve V, et al. Natural evolution of weight status in Duchenne muscular dystrophy: a retrospective audit. Br J 2011;105(10):1486-91.
10. Davidson ZE, Ryan MM, Kornberg AJ, Sinclair K, Cairns A, Walker KZ, et al. Observations of body mass index in Duchenne muscular dystrophy: a longitudinal study. Eur J Clin Nutr 2014;68(8):892-7.
11. Markham L, Spicer R, Khoury P, Wong B, Mathews K, Cripe LH. Steroid therapy and cardiac function in Duchenne muscular dystrophy. Pediatric cardiology. 2005;26:768-71.
12. Biggar W, Harris V, Eliasoph L, Alman B. Long-term benefits of deflazacort treatment for boys with Duchenne muscular dystrophy in their second decade. Neuromuscul Disord 2006;16(4):249-55.
13. Chew K, Carey K, Ho G, Mallitt K-A, Widger J, Farrar M. The relationship of body habitus and respiratory function in Duchenne muscular dystrophy. Respir Med 2016;119:35-40.
14. Billich N, Adams J, Carroll K, Truby H, Evans M, Ryan MM, et al. The Relationship between Obesity and Clinical Outcomes in Young People with Duchenne Muscular Dystrophy. Nutrients 2022;14(16):3304.
15. Goemans N, Wong B, Van den Hauwe M, Signorovitch J, Sajeev G, Cox D, et al. Prognostic factors for changes in the timed 4-stair climb in patients with Duchenne muscular dystrophy, and implications for measuring drug efficacy: A multi-institutional collaboration. PLoS One 2020;15(6):e0232870.
16. Sawnani H, Thampratankul L, Szczesniak RD, Fenchel MC, Simakajornboon N. Sleep disordered breathing in young boys with Duchenne muscular dystrophy. J Pediatr 2015;166(3):640-5. e1.
17. Bushby K, Connor E. Clinical outcome measures for trials in Duchenne muscular dystrophy: report from International Working Group meetings. Clin Investig 2011;1(9):1217.
18. Yağcıoğlu GA, Gürbüz İA, Topuz S, Yılmaz Ö. Development of a new instrument to evaluate gait characteristics of individuals with Duchenne Muscular Dystrophy: Gait Assessment Scale for Duchenne Muscular Dystrophy, and its validity and reliability. Early Hum Dev 2023;185:105843.
19. Neyzi O, Günöz H, Furman A, Bundak R, Gökçay

G, Darendeliler F. Türk çocuklarında vücut ağırlığı, boy uzunluğu, baş çevresi ve vücut kitle indeksi referans değerleri. Çocuk Sağlığı ve Hastalıkları Dergisi. 2008;51(1):1-14.
20. Organization WH, Organization WH. WHO Multicentre Growth Reference Study Group: WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: Methods and development. Geneva: WHO. 2006;2007.
21. Aydın Yağcıoğlu G. Duchenne Musküler Distrofi'li Hastalarda Yürüyüş Değerlendirme Ölçeği ile Yürüyüş Kalite ve Bağımsızlığı Sınıflandırma Skalası'nın Geliştirilmesi ve Geçerlilik ve Güvenilirliğinin İncelenmesi. 2021.
22. McDonald CM, Henricson EK, Abresch RT, Florence J, Eagle M, Gappmaier E, et al. The 6-minute walk test and other clinical endpoints in Duchenne muscular dystrophy: reliability, concurrent validity, and minimal clinically important differences from a multicenter study. Muscle Nerve 2013;48(3):357-68.
23. McDonald CM, Henricson EK, Han JJ, Abresch RT, Nicorici A, Elfring GL, et al. The 6-minute walk test as a new outcome measure in Duchenne muscular dystrophy. Muscle Nerve 2010;41(4):500-10.
24. Mukaka MM. A guide to appropriate use of correlation coefficient in medical research. Malawi Med J 2012;24(3):69-71.
25. Akoglu H. User's guide to correlation coefficients. Turkish J Emerg Med 2018;18(3):91-3.
26. Weber DR, Hadjiyannakis S, McMillan HJ, Noritz G, Ward LM. Obesity and endocrine management of the patient with Duchenne muscular dystrophy. Pediatrics 2018;142(Suppl 2):S43-S52.
27. Canapari CA, Barrowman N, Hoey L, Walker SW, Townsend E, Tseng BS, et al. Truncal fat distribution correlates with decreased vital capacity in Duchenne muscular dystrophy. Pediatr Pulmonol 2015;50(1):63-70.
28. Rodríguez-Cruz M, Sanchez R, Escobar RE, Cruz-Guzmán OdR, López-Alarcón M, Bernabe García M, et al. Evidence of insulin resistance and other metabolic alterations in boys with Duchenne or Becker muscular dystrophy. Int J Endocrinol 2015;2015.
29. McDonald CM, Abresch RT, Carter GT, Fowler Jr WM, Johnson ER, Kilmer DD, et al. Profiles of neuromuscular diseases. Duchenne muscular dystrophy. Am J Phys Med Rehabil 1995;74(5 Suppl):S70-92.
30. Hills AP, Parker AW. Gait characteristics of obese children. Arch Phys Med Rehabil 1991;72(6):403-7.
31. Galli M, Cimolin V, Rigoldi C, Condoluci C, Albertini G. Effects of obesity on gait pattern in young individuals with Down syndrome. Int J Rehabil Res 2015;38(1):55-60.
32. Elshemy SA. Comparative study: Parameters of gait in Down syndrome versus matched obese and healthy children. Egypt J Med Hum Genet 2013;14(3):285–91.
33. Donlevy GA, Garnett SP, Cornett KM, McKay MJ, Baldwin JN, Shy RR, et al. Association Between Body Mass Index and Disability in Children With Charcot-Marie-Tooth Disease. Neurology 2021;97(17):e1727-e36.
34. Meyns P, Van Gestel L, Bar-On L, Goudriaan M, Wambacq H, Aertbeliën E, et al. Children with spastic cerebral palsy experience difficulties adjusting their gait pattern to weight added to the waist, while typically developing children do not. Front Hum Neurosci 2016;10:657.
35. Del Porto H, Pechak C, Smith D, Reed-Jones R. Biomechanical effects of obesity on balance. Int J Exerc Sci 2012;5(4):301-20.
36. Bayram E, Topcu Y, Karakaya P, Bayram MT, Sahin E, Gunduz N, et al. Correlation between motor performance scales, body composition, and anthropometry in patients with duchenne muscular dystrophy. Acta Neurol Belg 2013;113(2):133-7.
37. Sussman MD, Sienko SE, Buckon CE, Hilton C, De Mattos CB, d'Amato C. Efficacy of corticosteroid in decreasing scoliosis and extending time to loss of ambulation in a single clinic: an effectiveness trial. J Child Orthop 2020;14(5):421-32.
38. Vuillerot C, Braillon P, Fontaine-Carbonnel S, Rippert P, André E, Iwaz J, et al. Influence of a two-year steroid treatment on body composition as measured by dual X-ray absorptiometry in boys with Duchenne muscular dystrophy. Neuromuscul Disord 2014;24(6):467-73.
39. Matthews E, Brassington R, Kuntzer T, Jichi F, Manzur AY. Corticosteroids for the treatment of Duchenne muscular dystrophy. Cochrane Database Syst Rev 2016;2016(5):CD003725.