Research Square

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Shunt Revision Frequency Is Associated with Motor Function and Anthropometric Growth in Pediatric Hydrocephalus

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Abstract

Objective

This study aimed to investigate the relationship between ventriculoperitoneal (VP) shunt revision frequency, motor functional level (Gross Motor Function Classification System; GMFCS), and anthropometric growth parameters in children with hydrocephalus.

Methods

A retrospective cohort analysis was conducted including 67 pediatric patients with hydrocephalus who were followed between 2010 and 2023 at a tertiary referral center. Demographic and anthropometric data (height, weight, head, waist, and hip circumferences) and motor function levels (GMFCS I–V) were collected. Patients were grouped according to the number of shunt surgeries: single versus multiple (≥ 2) revisions. Statistical analyses included independent-samples *t*-tests and multiple linear regression to determine the effects of surgical frequency and growth parameters on GMFCS levels.

Results

Of the 67 children, 28 (41.8%) required multiple shunt revisions. Patients in higher GMFCS categories (III–V) were significantly more likely to have undergone repeated surgeries compared with those in Levels I–II ($p < 0.05$). Anthropometric measurements—including height, weight, and circumferences—showed a decreasing trend with higher GMFCS levels, although not all reached statistical significance. In multivariable analysis, age and height were positively associated with GMFCS scores, while suprailiac skinfold thickness was negatively associated ($R^2 = 0.689$, $p < 0.001$).

Conclusions

Frequent VP shunt revisions are associated with poorer motor function and impaired physical growth in pediatric hydrocephalus. Early multidisciplinary management—including rehabilitation and nutritional support—should be prioritized for children with multiple shunt interventions to optimize neurodevelopmental outcomes.

Introduction

Hydrocephalus is a chronic neurological condition characterized by an imbalance between the production and absorption of cerebrospinal fluid (CSF), resulting in progressive ventricular dilation and elevated intracranial pressure. Affecting approximately 1 in 1000 live births, pediatric hydrocephalus remains one of the most common causes of neurosurgical intervention in childhood and can lead to lifelong motor, cognitive, and developmental impairments if not adequately managed [1, 2].

The ventriculoperitoneal (VP) shunt has been the standard treatment for more than six decades and continues to play a central role in managing pediatric hydrocephalus. Despite technological advances, shunt malfunction remains a significant clinical challenge, with failure rates reported as high as 40–60% during childhood [3, 4]. Each shunt revision carries additional risks, including infection, peritoneal adhesions, and further neurological injury. Repeated revisions not only increase morbidity and hospital stays but also negatively affect neurodevelopmental outcomes and overall quality of life [5, 6].

Motor function is a particularly sensitive indicator of neurodevelopmental health in children with hydrocephalus. The *Gross Motor Function Classification System (GMFCS)*, initially developed for cerebral palsy, has been validated as a standardized tool to evaluate gross motor capacity in various pediatric neurological disorders [7]. Higher GMFCS levels correspond to more severe motor limitation and are often accompanied by difficulties in feeding, postural control, and independent mobility. Consequently, GMFCS classification provides valuable insight into how neurological and systemic factors—including surgical burden—translate into functional ability.

Anthropometric measurements, such as height, weight, and head circumference, reflect both nutritional status and overall health in children. Growth impairment is common among those with chronic neurological diseases, and previous studies have shown that decreased mobility and feeding dysfunction contribute significantly to poor somatic growth [8, 9]. However, few studies have examined how repeated shunt revisions—representing cumulative surgical stress—interact with motor function and anthropometric parameters in pediatric hydrocephalus.

Therefore, the present study aimed to investigate the association between VP shunt revision frequency, GMFCS levels, and anthropometric growth patterns in children with hydrocephalus. By identifying how surgical and functional factors jointly influence growth outcomes, this study seeks to support more comprehensive and multidisciplinary follow-up strategies for affected patients.

Materials and Methods

Study Design and Population

This retrospective cohort study was conducted at the Pediatric Neurology Department of Zeytinburnu Training and Research Hospital, Istanbul, Türkiye. Medical records of pediatric patients diagnosed with hydrocephalus and treated with ventriculoperitoneal (VP) shunt surgery between January 2010 and December 2023 were reviewed. Inclusion criteria were: (1) diagnosis of congenital or acquired hydrocephalus confirmed by neuroimaging, (2) VP shunt placement performed during childhood, and (3) availability of complete medical records, including motor and anthropometric evaluations. Patients with genetic syndromes, chromosomal abnormalities, or severe comorbidities affecting growth were excluded.

A total of 67 children (35 females, 32 males) met the inclusion criteria. The mean age of participants at last follow-up was 43.4 ± 33.3 months. The study was approved by the Ethics Committee of Zeytinburnu

Training and Research Hospital (Approval No: 207, Date: 08.08.2025).

Data Collection and Variables

Demographic variables included sex, age, and etiology of hydrocephalus. Surgical history was obtained from hospital records, including the total number of VP shunt procedures. Patients were categorized into two groups based on shunt frequency: **Group 1**—single shunt procedure, and **Group 2**—multiple (≥ 2) shunt revisions.

Anthropometric parameters—height, weight, head circumference, waist circumference, and hip circumference—were recorded using standardized pediatric measurement techniques. Body mass index (BMI) and skinfold thickness (triceps and suprailiac) were calculated as indicators of nutritional and adiposity status.

Functional and Anthropometric Assessment

Motor function was assessed using the *Gross Motor Function Classification System (GMFCS)*, categorizing patients into five levels (I–V). Levels I–II were considered mild impairment, Level III moderate, and Levels IV–V severe impairment. All anthropometric data were interpreted according to the *World Health Organization (WHO) Child Growth Standards* [10].

Patients' anthropometric measurements and GMFCS levels were evaluated during their latest routine follow-up visits, at least six months after their last surgical procedure. This ensured assessment of stable postoperative status rather than transient post-surgical conditions.

Statistical Analysis

Data were analyzed using *IBM SPSS Statistics version 24.0* (Armonk, NY, USA). Normality of distribution was assessed by the Shapiro–Wilk test. Continuous variables were expressed as mean ± standard deviation (SD). Independent-samples *t*-tests were used to compare anthropometric variables and GMFCS scores between groups (single vs. multiple revisions). Associations between anthropometric parameters and GMFCS levels were assessed with Pearson correlation and multiple linear regression analysis.

A regression model was constructed to determine predictors of GMFCS score, including age, surgical frequency, and anthropometric variables. Statistical significance was set at $p < 0.05$.

Results

A total of 67 pediatric patients with hydrocephalus were included in the study. Of these, 39 (58.2%) had a single ventriculoperitoneal (VP) shunt procedure, while 28 (41.8%) required two or more surgical

revisions. The mean age of the cohort was **43.4 ± 33.3 months**, with **35 females (52.2%)** and **32 males (47.8%)**. No significant sex-related differences were observed in age, height, weight, or GMFCS distribution ($p > 0.05$).

GMFCS Distribution and Surgical Frequency

According to the *Gross Motor Function Classification System (GMFCS)*, 30 patients (44.8%) were classified as Levels I–II, 14 (20.9%) as Level III, and 23 (34.3%) as Levels IV–V. Children in higher GMFCS levels (III–V) were significantly more likely to have undergone multiple shunt revisions compared with those at lower functional levels ($p < 0.05$). This association indicates that increasing motor impairment parallels a higher frequency of surgical intervention (Table 1).

Table 1
Distribution of Patients According to GMFCS Levels and Shunt Revision Frequency

GMFCS Level	n (%)	Single Shunt (n)	Multiple Revisions (n)	p-value
Level I–II	30 (44.8%)	25	5	< 0.05*
Level III	14 (20.9%)	8	6	0.07
Level IV–V	23 (34.3%)	6	17	< 0.05*
Total	**67 (100%)**	**39**	**28**	

*Statistically significant difference between GMFCS categories in relation to revision frequency.

Anthropometric Parameters

The mean anthropometric values of the entire cohort were as follows:

Height = **88.1 ± 18.7 cm**, Weight = **15.4 ± 8.8 kg**, Head circumference = **48.9 ± 4.6 cm**, Waist circumference = **49.3 ± 8.3 cm**, and Hip circumference = **51.2 ± 9.6 cm**.

When stratified by GMFCS levels, a progressive decline in height, weight, and circumference measurements was observed with increasing GMFCS scores (Table 2).

Table 2
Anthropometric Measurements According to GMFCS Levels

GMFCS Level	Height (cm)	Weight (kg)	Head Circ. (cm)	Waist Circ. (cm)	Hip Circ. (cm)
I	88.1 ± 18.0	14.6 ± 8.5	48.4 ± 4.2	49.1 ± 7.8	51.1 ± 9.7
II	97.0 ± 17.0	17.4 ± 6.7	50.7 ± 2.9	52.9 ± 10.8	56.1 ± 9.1
III	128.5 ± 26.2	35.2 ± 13.9	52.5 ± 0.7	62.5 ± 6.4	75.0 ± 8.5
IV	84.6 ± 16.1	14.4 ± 8.1	48.9 ± 5.2	48.1 ± 7.7	49.0 ± 7.7
V	80.3 ± 19.8	13.2 ± 7.6	47.5 ± 4.9	47.0 ± 6.9	48.2 ± 7.2

Values are presented as mean ± SD. Differences across GMFCS levels were not statistically significant ($p > 0.05$) except for the overall downward trend in height and weight with increasing GMFCS level.

As shown in Fig. 1, all anthropometric measurements—including height, weight, head, waist, and hip circumferences—tended to decrease as GMFCS level increased, demonstrating an inverse relationship between motor capacity and physical growth. Children with mild or moderate impairment (Levels I–III) showed relatively preserved growth profiles, whereas those with severe functional limitation (Levels IV–V) exhibited clear reductions across all growth indicators.

Regression Analysis

A multiple linear regression model was constructed to examine the combined effects of age, surgical frequency, and anthropometric variables on GMFCS level.

The overall model was statistically significant ($R^2 = 0.689$, $F = 15.43$, $p < 0.001$), indicating that approximately 69% of the variability in GMFCS scores could be explained by the included predictors.

Among the variables, **age** ($t = 2.65$, $p = 0.011$) and **height** ($t = 3.80$, $p < 0.001$) were significantly and positively associated with better GMFCS performance, suggesting that older and taller children tended to have higher gross-motor capacities. Conversely, **suprailiac skinfold thickness** was negatively associated with GMFCS ($t = -2.43$, $p = 0.018$), implying that greater adiposity may correspond to lower gross-motor function (Table 3).

Table 3
Multiple Linear Regression Analysis for Predictors of GMFCS Level

Independent Variable	B	SE	β (Beta)	t	p-value
Age (months)	0.207	0.078	0.366	2.65	0.011*
Height (cm)	1.054	0.277	0.494	3.80	< 0.001*
Suprailiac Skinfold (mm)	−8.671	3.566	−0.207	−2.43	0.018*
Waist Circumference (cm)	0.231	0.211	0.154	1.09	0.281
Hip Circumference (cm)	0.116	0.095	0.132	1.21	0.231
Model Summary			**R^2 = 0.689**	**F = 15.43**	**p < 0.001**

Regression model includes age, height, suprailiac skinfold, waist, and hip circumferences as independent variables. Statistically significant predictors are indicated with an asterisk.

Other anthropometric measures, including waist and hip circumference, were not independent predictors in the model ($p > 0.05$).

Discussion

This study examined the interrelationship between ventriculoperitoneal (VP) shunt revision frequency, gross motor function, and anthropometric growth in pediatric hydrocephalus over a 14-year period. The results demonstrate that children who required multiple shunt revisions exhibited poorer motor performance, reflected by higher GMFCS levels, and showed an overall decline in growth parameters compared to those who underwent a single procedure.

Our findings are consistent with previous research emphasizing the adverse neurodevelopmental impact of repeated shunt interventions. Multiple revisions often indicate underlying disease complexity and expose the developing brain to additional surgical stress, infection risk, and fluctuations in intracranial pressure, which may exacerbate neural injury [1–3]. Several authors, including Kahle et al. and Khan et al., reported that recurrent shunt failure correlates with cognitive delay, spasticity, and reduced adaptive function [4, 5]. In our cohort, a similar pattern was evident, suggesting that revision frequency may serve both as a marker of disease severity and as a contributor to secondary neurological damage.

The decline in anthropometric parameters among patients with higher GMFCS levels supports the concept that mobility and somatic growth are interdependent. Reduced activity, feeding difficulties, and increased metabolic demands in severely affected children often result in malnutrition and growth failure [6, 7]. Our regression analysis identified height as a significant positive predictor of motor function, while suprailiac skinfold thickness—an indicator of central adiposity—showed a negative correlation. This finding is in line with studies suggesting that lower lean body mass and greater fat accumulation accompany decreased muscle tone and limited movement [8, 9].

From a clinical standpoint, these results highlight the importance of multidisciplinary follow-up for children with hydrocephalus. Early rehabilitation focusing on mobility and posture, combined with regular anthropometric and nutritional assessment, may mitigate the compounding effects of repeated surgical interventions. Incorporating growth tracking into neurosurgical follow-up could serve as a simple yet valuable tool to identify patients at risk for motor deterioration.

Future studies should extend these observations through multicenter, prospective designs, integrating neurodevelopmental and metabolic outcomes. The interplay between surgical history, growth, and neuroendocrine regulation—particularly the effects of chronic stress, corticosteroid exposure, and growth hormone axis dysfunction—deserves further investigation.

Limitations

This study has several limitations. Its retrospective and single-center design limits generalizability and introduces potential selection bias. The sample size, particularly for GMFCS Level V, was relatively small, reducing the statistical power to detect subtle differences among subgroups. Additionally, detailed information on shunt type, valve design, and specific causes of revision (e.g., infection vs. obstruction) was not available. Anthropometric measures such as skinfolds provide indirect estimates of body composition; future research using objective techniques (e.g., DXA, bioimpedance) would improve accuracy. Finally, the absence of standardized neurocognitive assessments prevents correlation between motor and cognitive outcomes.

Conclusion

Frequent VP shunt revisions are significantly associated with poorer motor performance and impaired growth in children with hydrocephalus. These findings underscore the importance of early, multidisciplinary management integrating neurosurgical, nutritional, and rehabilitative care. Regular monitoring of both GMFCS level and growth parameters should be considered a standard part of follow-up protocols to enhance long-term neurodevelopmental outcomes.

Declarations

Funding: The authors received no financial support for the research, authorship, or publication of this article.

Conflict of Interest: The authors declare no conflicts of interest.

Ethical Approval: This study was approved by the Ethics Committee of Zeytinburnu Training and Research Hospital (Approval No: 207, Date: 08.08.2025).

Accordance Statement: The study was conducted in accordance with the Declaration of Helsinki and the ethical standards of the institutional research committee.

Consent to Participate: Informed consent was obtained from all individual participants (or their legal guardians) included in the study.

Consent to Publish: Not applicable.

Data Availability Statement: The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Author Contribution

Necati Taşkın: Conceptualization, study design, data collection, manuscript draftingFatmanur Kesiktaş: Data analysis, statistical evaluation, interpretation of resultsİbrahim Burak Atçı: Surgical data review, methodology validation, manuscript editingÖmer Akçağıl: Clinical data acquisition, patient follow-up, data verificationİlkiz Özge ÖzdilYılmaz: Anthropometric data collection, literature review, figure preparationTeoman Akçay: Supervision, final manuscript approval, corresponding author dutiesAll authors read and approved the final version of the manuscript and agree to be accountablefor all aspects of the work.

References

1. Kahle KT, Kulkarni AV, Limbrick DD Jr, Warf BC. Hydrocephalus in children. Lancet. 2016;387(10020):788–99. 10.1016/S0140-6736(15)60694-8.
2. Vinchon M, Dhellemmes P. Cerebrospinal fluid shunt infection: risk factors and long-term follow-up. Childs Nerv Syst. 2020;36(5):1105–14. 10.1007/s00381-020-04570-2.
3. Simon TD, Riva-Cambrin J, Srivastava R, et al. Hospital care for children with hydrocephalus in the United States: utilization, charges, comorbidities, and deaths. J Neurosurg Pediatr. 2008;1(2):131–7. 10.3171/PED/2008/1/2/131.
4. Khan F, Rehman A, Ullah H, et al. Neurodevelopmental outcomes of children with hydrocephalus treated with ventriculoperitoneal shunt: a prospective cohort study. Childs Nerv Syst. 2021;37(10):3211–8. 10.1007/s00381-021-05215-4.
5. Vinchon M, Rekate H, Kulkarni AV. Pediatric hydrocephalus outcomes: a review. Fluids Barriers CNS. 2012;9(1):18. 10.1186/2045-8118-9-18.
6. Aukrust CG, Lundberg F, Gulati S, et al. It is the child with the big head: primary management and head-circumference growth in paediatric hydrocephalus. Glob Public Health. 2023;18(8):1–11. 10.1080/17441692.2023.2276242.
7. Palisano R, Rosenbaum P, Walter S, et al. Development and reliability of a system to classify gross motor function in children with cerebral palsy. Dev Med Child Neurol. 1997;39(4):214–23. 10.1111/j.1469-8749.1997.tb07414.x.

8. Scharf RJ, et al. Early childhood growth and cognitive outcomes: findings from a global analysis. Matern Child Nutr. 2018;14(Suppl 4):e12584. 10.1111/mcn.12584.
9. Grace N, et al. High burden of wasting among children under-five with hydrocephalus. PeerJ. 2024;12:e15890. 10.7717/peerj.15890.
10. World Health Organization. WHO Child Growth Standards: Methods and Development. Geneva: WHO; 2006.
11. Pan P, et al. Outcome analysis of ventriculoperitoneal shunt surgery in children with hydrocephalus and evaluation of risk factors for shunt failure. J Pediatr Neurosci. 2018;13(2):124–9. 10.4103/JPN.JPN_35_18.
12. Mansoor N, et al. Shunt complications and revisions in children: a systematic overview. Brain Behav. 2021;11(8):e2390. 10.1002/brb3.2390.
13. Rekate HL. Shunt-related headaches: the slit ventricle syndromes. Childs Nerv Syst. 2008;24(4):423–30. 10.1007/s00381-007-0518-4.
14. Tully HM, Dobyns WB. Infantile hydrocephalus: a review of epidemiology, classification and causes. Eur J Med Genet. 2014;57(8):359–68. 10.1016/j.ejmg.2014.06.002.
15. Warf BC. Combined endoscopic third ventriculostomy and choroid plexus cauterization for infant hydrocephalus. Neurosurg Focus. 2005;19(6):E1. 10.3171/foc.2005.19.6.2.

Figures

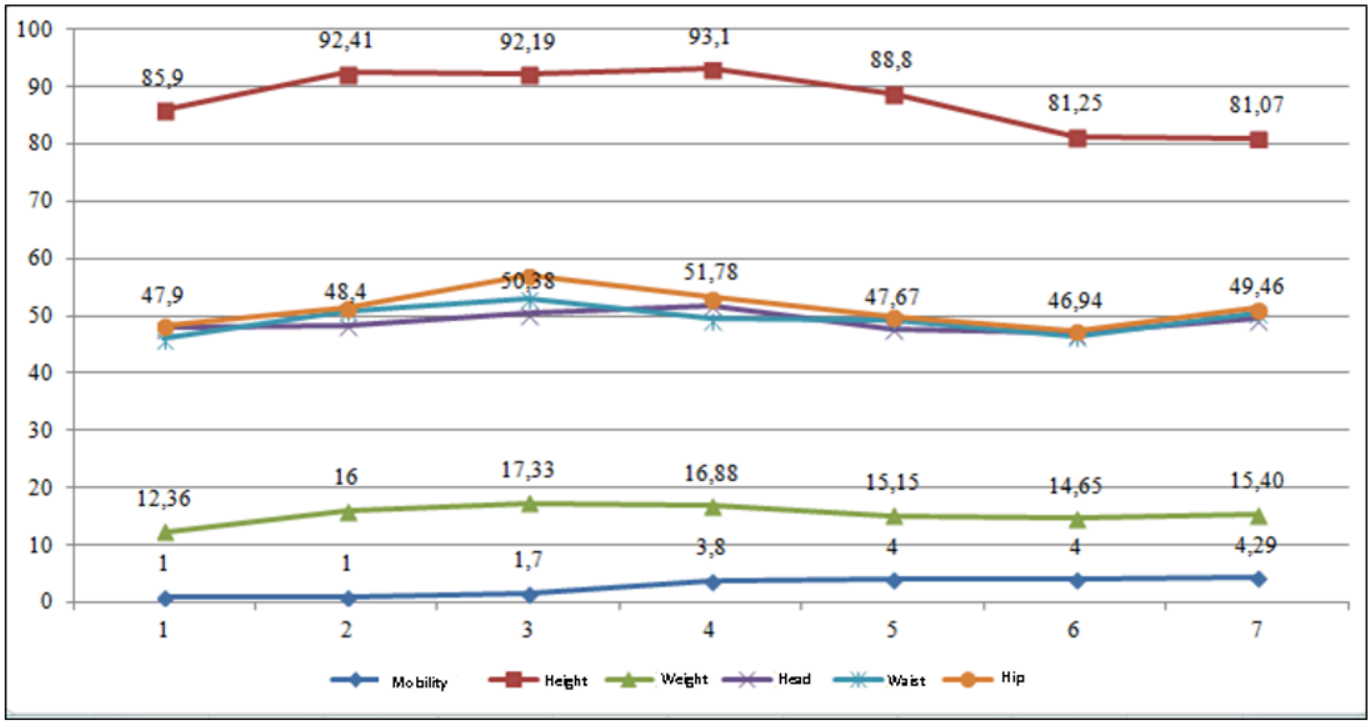


Figure 1

Relationship between anthropometric measurements and GMFCS levels in pediatric hydrocephalus.