Is Motor Performance in 5.5-Year-Old Children Associated with the Presence of Generalized Joint Hypermobility?

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Objective To determine the prevalence of generalized joint hypermobility (GJH) in Dutch children aged 5.5 years, and to examine the association between GJH and motor performance and development over time.

Study design A prospective cohort of 249 children was recruited. GJH was assessed with the Beighton test at age 5.5 years. Motor performance was evaluated at age 2.0 years using the Bayley Scales of Infant Development, Second Edition and at age 5.5 years using the Movement Assessment Battery for Children–Second Edition (subscore categories: manual dexterity, aiming and catching, and static and dynamic balance).

Results In 249 children, the prevalence of GJH, defined by the Beighton test score, was 34.1% for a score ≥4, 22.5% for a score ≥5, and 16.5% for a score ≥6. No significant association was found between GJH and total motor performance. Manual dexterity in girls (Beighton score ≥4) was positively associated with higher level of motor performance (β [SE] = 0.38 [0.17]; P = .028), ranging from +0.04 SD to +0.72 SD, even after correction for covariates. A significant interaction between GJH and body mass index (BMI) growth was found, indicating that the effect of GJH on the rate of development of motor performance declines with increasing BMI growth (β = 0.05 [0.02]; P = .031).

Conclusion In this healthy pediatric cohort, GJH was present in one-third of the sample, and no significant association was found between GJH and total motor performance. The effect of GJH on the rate of development of motor performance appears to decline with increasing BMI growth. Longitudinal prospective studies are recommended to detect influences of GJH on motor performance over time, as well as the influence of body composition and Beighton cutoff points. *(J Pediatr 2015; ■: ■-■)*.

Generalized joint hypermobility (GJH) is common in children. When arthralgia in more than 4 joints is present for longer than 3 months without any signs of rheumatic, neurologic, skeletal, or metabolic disease, hypermobility syndrome (HMS) can be diagnosed.[1] The presence of GJH in children is commonly detected using the Beighton test. This measure is considered the gold standard from infancy to old age.[2-5] Use of the Beighton test is controversial, however, owing to a lack of standardization in children, as well as a lack of age-, sex-, and ethnicity-specific cutoff values.[2,4,6]

The prevalence of GJH is unclear, with extensive variation reported in the relevant literature. This could be explained by the absence of an international consensus and the lack of operationalization standards, which vary according to differences in study populations, cutoff levels, and actual administration of the Beighton test.[2,6-8] Murray et al[9] reported GJH prevalence ranging between 2% and 55% in various pediatric populations. Recent studies have examined the heterogeneity of GJH in the Caucasian population by comparing the prevalence of GJH at varying cutoff levels and taking age and sex into consideration.[2,4,6,10,11] Differences in cutoff levels also might be explained by the more precise and detailed descriptions of standard operating procedures used for measuring local joint hypermobility and GJH, as first described by Juul-Kristensen et al.[3]

The concurrent validity of the Beighton test in relation to goniometry has been found to be high.[4] Regarding predictive value, one study found that 10-year-old children diagnosed with GJH and musculoskeletal pain using the Beighton test had an increased risk of persistent pain at age 14 years.[12]

Despite the prevalence of GJH in normal populations,[13,14] much remains unknown about its consequences. GJH has been associated with a wide variety of musculoskeletal complaints, including joint pain, dysfunction of various organ systems (eg, blood vessels and skin), and psychosocial problems.[2,6,15-18] GJH is associated with an increased incidence of motor delay in infancy, with

AICC	Akaike information criterion
BMI	Body mass index
BSID-II	Bayley Scales of Infant Development, Second Edition
GJH	Generalized joint hypermobility
HMS	Hypermobility syndrome
MD	Mean difference
Movement ABC-2	Movement Assessment Battery for Children–Second Edition

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catch-up occurring in most children by age 2 years.[19] In one study, however, at age 5 years, motor performance was significantly delayed in children who exhibited joint hypermobility and motor delay at age 18 months.[20] Adib[21] reported clumsiness, poor motor coordination in early childhood, and problems with handwriting tasks. Engelbert et al[22] observed severe delay in motor development in approximately one-third of children with GJH, with no association with the number of hypermobile joints.[22] Juul-Kristensen et al[10] and Remvig et al[2] evaluated the prevalence of GJH (at different cutoff levels) in primary school children at age 8 and 10 years and concluded that motor competence was not delayed.

In the cohort reported here, we previously determined the relationship between joint hypermobility and motor performance with and without developmental coordination disorder, and found a significant negative correlation between joint mobility and motor performance in the children with developmental coordination disorder, but not in the group of typically developing children.[23]

The purpose of the current study was 3-fold: (1) to determine the prevalence of GJH as defined by the Beighton test at various cutoff levels in Dutch children aged 5.5 years; (2) to study the association between GJH and specific issues of motor performance at age 5.5 years; and (3) to evaluate the consequences of GJH on the rate of motor development over time in children aged 2.0 years and 5.5 years.

Methods

We recruited 249 healthy Dutch children (mean age, 5.5 years) from a birth cohort study of 400 healthy term neonates at the General District Hospital Bernhoven at Veghel, The Netherlands. This cohort was part of 2 earlier studies by van Vlimmeren et al,[24,25] in which assessment of motor performance was performed at age 2 and 5.5 years. Assessments were performed by a team of 12 qualified pediatric physiotherapists. The interrater reliability was high, measured before the start of the study (intraclass correlation >0.8). Medical ethical approval was given by the Committee for Medical Ethics at University Medical Center Utrecht, Radboud University Medical Center, and Bernhoven Hospital Veghel, The Netherlands. Written informed consent was obtained from all parents in accordance with the Declaration of Helsinki.

Anthropometry

Demographic data were collected regarding age, sex, height, and weight. Standing height and weight were measured using a standardized method (wearing underwear and bare feet, measured to the nearest 1 cm and 100 g, respectively). Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared.[26]

GJH According to Beighton Score

To determine the presence of GJH, the protocol published by Smits-Engelsman et al[4] was used. The Beighton test is a reliable[3] and valid instrument for classifying GJH in primary school-aged children.[4] The Beighton test consists of 5 clinical maneuvers and is scored dichotomously (0-1). A total score (ranging from 0 to 9) was derived by summing all maneuvers: (1) bilateral passive apposition of the thumb to the flexor side of the forearm, with positive score if the whole thumb touches the flexor side of the forearm (shoulder 90° flexed, elbow extended, and hand pronated); (2) bilateral passive dorsiflexion of the fifth metacarpophalangeal joint ≥90° (sitting on chair, arm in 80° abduction, elbow flexed 90°, forearm resting on a table, forearm pronated); (3) bilateral passive hyperextension of the elbow ≥10° (sit on chair with shoulder 90° anteflexion, forearm supinated); (4) bilateral passive hyperextension of the knee ≥10° (lying supine with legs supported by a table); and (5) forward flexion of the trunk, with knees straight, so that the palms of the hands rest easily on the floor.[4]

The presence of GJH was used for analysis at 3 cutoff points: Beighton score ≥4 (GJH4), Beighton score ≥5 (GJH5), and Beighton score ≥6 (GJH6). We used these different cutoff points because the correct cutoff point in children is still under discussion (number of positive items, related to sex). When applying GJH7, only 25 (19 girls) children were scored with GJH. When these data were applied to the model, the basic statistical assumptions could not be fulfilled, owing to the variance of the outcomes in relation to the small subsample size.

Motor Performance Tests

Motor performance was determined by age-appropriate test batteries at age 2.0 years by the motor scale of the Bayley Scales of Infant Development, Second Edition (BSID-II)[27] and at age 5.5 years by the Movement Assessment Battery for Children–Second Edition (Movement ABC-2).[28,29] For both the BSID-II and Movement ABC-2, the deviation of normality on the basis of normative values was incorporated into the scores.

In the total cohort, the English version of the BSID-II was used to score motor performance at age 2.0 years.[27] This instrument comprises 3 scales—the mental, motor, and behavior rating scales—but only the motor scale was used for the present study. The motor scale is a highly reliable, valid, and norm-referenced instrument for evaluating the general development of infants aged 1-42 months.[27] This scale consists of 111 items that measure skills related to gross and fine motor control. The items in the motor scale are task items, scored dichotomously. Raw scores were converted into a Psychomotor Developmental Index score, which has a mean (SD) of 100 (15).[27]

The Movement ABC-2 was used to assess motor performance at age 5.5 years. The Movement ABC-2 is a standardized and norm-referenced test, validated for the Dutch population, that aims to classify children aged 3-16 years according to degree of motor performance.[28,29] This test consists of 8 items in each of 3 age groups (3-6 years, 7-10 years, and 11-16 years). These items measure different aspects of motor performance divided into 3 major areas: manual dexterity, aiming and catching, and static and dynamic balance. For each child, the raw item scores were

transformed into an item standard score, a component standard score, a total standard score, and a total percentile score. The mean of the item standard score, component standard score, and total standard score is 10.[30] This instrument has good concurrent validity (r = 0.58-0.62) and good reliability (intraclass correlation = 0.95-0.98).[28,29] Of the aforementioned motor performance tests, only assessments of motor skills were used in our analysis.

Data Analysis and Statistics

Descriptive statistics were used to describe all relevant variables. Skewness and normality of data were inspected visually and checked using the Kolmogorov-Smirnov test. Normally distributed data are expressed as mean and SD; skewed data, as median and IQR.

The anthropometric data on BMI, height, and weight were converted into sex-specific BMI-for-age scores, height-for-age scores, and weight-for-age scores, using the SPSS macro growth standards developed by the World Health Organization. With respect to sex, differences in the prevalence of GJH4, GJH5, and GJH6 were analyzed using the χ^2 test.

To construct multivariate longitudinal models, factor identification was performed by univariate analysis for the factor sex (boys vs girls) and GJH (GJH4, GJH5, and GJH6). Normally distributed variables were analyzed by an independent t test, and non-normally distributed data were analyzed by the Mann-Whitney U test. Variables were retained for multivariate analysis when a P value of <.20 was ascertained.[31] Retained factors were entered in the mixed linear regression analysis to determine the influence of GJH on motor development. For each cutoff level for GJH (GJH4, GJH5, and GJH6), a separate linear mixed regression model was constructed in which motor development was the dependent factor and the presence of GJH at age 5.5 years was the independent factor. To aid clinical interpretation and prevent multicollinearity, all outcomes were group centered by z-score transformation. These models were corrected for potential confounders (sex and BMI). Time (T0, 2.0 years; T1, 5.5 years) was inserted in mixed-effects models to determine the progression over time (repeated covariance: first-order ante dependence). Results are presented as an unstructured regression coefficient (β) and SE with 95% CI. Results were considered statistically significant at a P value <.05. All analyses were performed with SPSS 22.0 (IBM, Armonk, New York).

Results

Table I reports data regarding the hypermobility assessment, number and age of children, and cutoff level of the instrument used in previous corresponding studies. Our total cohort consisted of 249 Dutch children, including 138 girls (55.4%) and 111 boys (44.6%). The mean (SD) age was 5.50 (0.18) years in girls and 5.52 (0.20) years in boys (Table II). Univariate analysis at age 5.5 years revealed a significant difference between girls and boys regarding height-for-age and weight-for-age, but no difference in BMI-for-age (Table II).

In the total sample, at age 5.5 years, the prevalence was 34.1% for GJH4, 22.5% for GJH5, and 16.5% for GJH6. There was a significantly higher prevalence of GJH among girls than among boys at all 3 cutoff levels (Table II). The distribution of hypermobile joints is presented in Table III. At age 5.5 years in the total study population, the upper extremities showed a significantly higher prevalence of joint hypermobility than the trunk/lower extremities. There was no significant difference in the prevalence of joint hypermobility of the upper extremities between boys and girls. In contrast, girls had significantly more hypermobility in the knees and trunk than boys.

Univariate Analysis

Univariate analysis regarding the differences between boys and girls with GJH (GJH4, GJH5, and GJH6) and those without GJH on motor performance at age 5.5 years are displayed in Table IV. Significantly higher scores for dexterity were found for girls classified with GJH4 (mean difference [MD] [95% CI]: 0.34 [0.04-0.63], P = .025), suggesting that girls with GJH4 have increased dexterity, ranging +.04 SD to +.63 SD. Non-significant trends were found at GJH5 (MD [95% CI]: 0.29 [−0.04 to 0.63], P = .087) and at GJH6 (MD [95% CI]: 0.33 [−0.05 to 0.70], P = .087). For all outcomes, significantly higher levels of motor performance were observed in girls classified with GJH (GJH4, GJH5, GJH6). Similar results were observed in boys: subjects with GJH (GJH4, GJH5, GJH6) had higher scores on all outcomes than non GJH. Regarding dexterity, boys with GJH4 had significantly higher scores (MD [95% CI]: 0.28 [0.04-0.52], P = .025), indicating boys with GJH4 to have increased dexterity, ranging from +.04 SD to +.52 SD. All other outcomes failed to reach significance. Based on the univariate analysis the following outcomes were retained for multivariate analysis: sex, BMI, GJH4, GJH5, and GJH6.

Multivariate Analysis: Cross-Sectional

In the total population, the results indicated that at age 5.5 years, there was no significant association between GJH and motor performance, corrected for the covariates height, weight, and the interaction between height and weight. Notably, non-significantly higher z-scores on motor performance in children with GJH in all three cut-off levels compared with non-GJH were found irrespective of sex (Table IV).

Results of the multiple linear regression models for motor performance are presented in Table V (available at www.jpeds.com). All the necessary assumptions for multiple linear regression were fulfilled. Data demonstrated that manual dexterity in girls (GJH4) was positively associated with higher level of motor performance (β [SE]: 0.38 [0.17], P = .028), ranging from +0.04 SD to +0.72 SD.

Table I. Clinical characteristics and instruments for assessing hypermobility

Authors	Year of publication	Measurement identifying GJH	Cutoff for diagnosing GJH	Total subjects, n	Girls/boys, n	Age, y, mean (SD) or range
Remvig et al[2]	2011	Beighton test	GJH4 GJH5 GJH6	315	159/156	10.1 (0.35) y
Smits-Engelsman et al[4]	2011	Standardized Beighton test protocol	GJH5 GJH7	551	293/258	6-12 y
van der Giessen et al[5]	2001	Beighton test	GJH4	773	378/395	4-12 y
Clinch et al[6]	2011	Beighton test	GJH4 GJH6	6022	3061/2961	13.8 y
Lamari et al[8]	2005	Beighton test	GJH4	1120	586/534	4-7 y
Juul-Kristensen et al[10]	2009	Beighton test	GJH4 GJH5 GJH6	349	160/189	8.4 (0.52) y
Leone et al[11]	2009	Beighton test	GJH5	1046	516/530	6.7-15.3 y
El-Metwally et al[12]	2004	Beighton test	GJH6	403	209/194	10.7 y
Engelbert et al[15]	2003	Bulbena scale	5/10 (girls) 4/10 (boys)	110	63/47	4-12 y
Fatoye et al[16]	2009	Beighton test	GJH6	66*	38/28	8-15 y
Fatoye et al[17]	2011	Beighton test	GJH6	66*	38/28	8-15 y
Juul-Kristensen et al[18]	2012	Beighton test	GJH5	39	19/20	10.2 y
Jaffe et al[19]	1988	Carter-Wilkinson test + 2 additional tests	Not specified	717	352/365	8-12 mo
Tirosh et al[20]	1991	Carter-Wilkinson test + 2 additional tests	Not specified	60	Not specified	54-60 mo
Adib[21]	2005	Beighton test	GJH4	125†	67/58	3-17 y
Engelbert et al[22]	2005	Bulbena scale	5/10 (girls) 4/10 (boys)	72	30/42	1.3-11.6 y
Jelsma et al[23]	2013	Standardized Beighton test protocol	GJH4‡ GJH5¶	388§	183/169	3-16 y
Qvindesland and Jonsson[32]	1999	Beighton test	GJH4	267	143/124	12.4 y
Jansson et al[33]	2004	Beighton test	GJH4	1845	895/950	9-15 y
Quatman et al[34]	2008	Beighton test and Horan joint mobility index	Not specified	418	275/143	11-18 y
Tobias et al[37]	2013	Beighton test	GJH6	2901	1634/1267	13.8-17.8 y
Kirby and Davies[43]	2007	Questionnaire based on a 5-part questionnaire for identifying hypermobility	Not specified	54§	14/40	5-18 y

*Subjects with HMS and those without HMS.
†Subjects with HMS.
‡Subjects aged 3-9 years.
§Subjects with developmental coordination disorder and typically developing children.
¶Subjects aged 10-16 years.

Multivariate Analysis: Longitudinal

Three mixed linear regression models were constructed for the Beighton cutoff levels: GJH4, GJH5, and GJH6 (**Table VI**; available at www.jpeds.com). In the model for GJH4 (Akaike information criterion [AICC] = 692.5), higher levels of motor performance were associated with the presence of GJH (β [SE] = 0.86 [0.39]; P = .030). This finding indicates that children with GJH have a higher rate of development of motor performance, ranging from +0.09 SD to +1.64 SD. Sex (β [SE] = 0.10 [0.07]; P = .124) and BMI growth (β [SE] = 0.04 [0.02]; P = .059) both modified (albeit nonsignificantly) the association between motor performance and GJH. A significant interaction between GJH and BMI growth was present, indicating that the effect of GJH on the rate of development of motor performance declines with increasing BMI growth (β [SE] = −0.05 [0.02]; P = .031).

In the model for GJH5 (AICC = 695.4), higher rates of development of motor performance were associated with the presence of GJH (β [SE] = 0.18 [0.45]; P = .688). The effect of GJH ranged from −0.71 SD to +1.06 SD. Other factors also failed to contribute to the effect of GJH on the rate of development of motor performance.

In the model for GJH6 (AICC = 697.7), a higher, but nonsignificant rate of development of motor performance was again associated with the presence of GJH (β [SE] = 0.33 [0.55]; P = .549). The effect of GJH ranged from −0.75 SD to +1.42. SD. Other factors also failed to contribute significantly to the effect of GJH on the rate of development of motor performance. In all 3 models, age at assessment was a significant factor in the rate of development of motor performance regardless of the presence of GJH ($P \leq .0001$).

Discussion

This population-based cohort study found a prevalence of 34.1% for GJH4, 22.5% for GJH5, and 16.5% for GJH6 at age 5.5 years, with prevalence higher in girls than in boys at

Table II. Clinical characteristics by sex

Characteristics	Girls	Boys	*P* value
Sex, n (%)	138 (55.4)	111 (44.6)	.10
Age, y, mean (SD)	5.50 (0.18)	5.52 (0.20)	.44
Beighton cutoff, n (%)			
GJH4	59 (42.8)	26 (23.4)	**.001**
GJH5	41 (29.7)	15 (13.5)	**.002**
GJH6	29 (21)	10 (9.0)	**.031**
Anthropometric data, *z*-score, mean (SD)			
Height-for-age	0.70 (0.91)	0.97 (1.0)	**.026**
Weight-for-age	0.39 (0.75)	0.68 (0.93)	**.006**
BMI-for-age	−0.06 (0.91)	0.11 (0.91)	.147
Motor performance, *z*-score, median (IQR)			
Movement ABC-2 manual dexterity	0.33 (0-1)	0 (−0.33 to 1)	**.002**
Movement ABC-2 aim and catch	0 (−0.67 to 0.33)	0.33 (−0.33 to 1)	**.002**
Movement ABC-2 balance	−0.33 (−0.67 to 0.67)	−0.33 (−0.67 to 0.67)	.40
Movement ABC-2 total	0.33 (−0.33 to 1)	0 (−0.67 to 1)	.451
BSID-II *z*-score	−1.2 (−1.33 to −0.93)	−1.13 (−1.33 to −1)	.571

P values in bold type are statistically significant ($P < .05$).

all 3 cutoff levels. In this cohort, the prevalence of hypermobile joints was higher in the upper extremities compared with the trunk/lower extremities. There was no significant sex-based difference in the upper extremities, but a significantly higher percentage of girls had hypermobility in the trunk/lower extremities. Regarding motor performance and the rate of motor development, subjects with GJH (at all 3 cutoff values) showed no significant differences in motor performance and development at age 2.0 years and age 5.5 years.

This study reports on a relatively large population of children at age 5.5 years who were classified as GJH4. As mentioned previously, the classification and prevalence of GJH are influenced by numerous factors, including age, sex, ethnicity, standardized testing, and cutoff level used.[2,6-8]

Given the narrow age range of our study cohort, it can be assumed that the influence of age on the prevalence of GJH in this cohort is negligible. Comparing our findings with the results reported from 4 recent narrow age range studies assessing children at age 8 years,[2] 10 years,[6] 12 years,[10] and 14 years[32] shows a decrease in the prevalence of GJH with increasing age with respect to the same cutoff levels. Girls demonstrated significantly higher rates of GJH than boys at all 3 cutoff levels.

These findings are in line with 2 large school-based studies from Italy[11] and Sweden,[33] as well as a large population-based cohort study from the United Kingdom,[6] but are in contrast to findings in the previously mentioned studies of Juul-Kristensen et al,[10] Remvig et al,[2] and Smits-Engelsman et al.[4] Puberty may play an important role. Quatman et al[34] found that female athletes experienced an increase in GJH after the onset of puberty, whereas male athletes did not demonstrate any significant change. Prevalence studies have confirmed a higher incidence of GJH in females compared with males, which might be related to differences in the ratio of elastic vs collagen fibers, as well as hormonal fluctuations, which have a profound effect on connective tissue stiffness.[35] The effect of racial/ethnic differences on the prevalence of GJH remains unknown. These data were not recorded in the present study; however, it is very likely that the majority of our subjects were of Caucasian origin, based on the ethnic structure of the population from which the birth cohort was selected.[36]

The prevalence of GJH in children in previous studies also was strongly influenced by the applied Beighton cutoff level. Some authors have suggested that the prescribed cutoff level of ≥4 is too low for screening GJH in children because of the high prevalence.[4,6,33] Smits-Engelsman et al[4] and Jansson et al[33] determined the cutoff level for the classification of GJH in their study population (Beighton score ≥7) based on statistical standards for including only the extremes of GJH. In our opinion, defining a cutoff level based on

Table III. Prevalence of positive Beighton maneuvers (left-right) by sex

Beighton maneuver (0-9)	Girls (n = 138), n (%)	Boys (n = 111), n (%)
Passive dorsiflexion of the left fifth metacarpophalangeal joint ≥90°	51 (37.0)	32 (28.8)
Passive dorsiflexion of the right fifth metacarpophalangeal joint ≥90°	48 (34.8)	27 (24.3)
Passive apposition of the left thumb to the flexor side of the forearm	51 (37.0)	42 (37.8)
Passive apposition of the right thumb to the flexor side of the forearm	48 (34.8)	39 (35.1)
Passive hyperextension of the left elbow ≥10°	49 (35.5)	31 (27.9)
Passive hyperextension of the right elbow ≥10°	51 (37.0)	29 (26.1)
Passive hyperextension of the left knee ≥10°	45 (32.6)*	14 (12.6)*
Passive hyperextension of the right knee ≥10°	46 (33.3)*	13 (11.7)*
Forward flexion of the trunk, with knees straight, so that the palms of the hands rest easily on the floor	38 (27.5)*	10 (9.0)*

*$P < .05$, indicating a statistically significant sex-based difference in prevalence.

Table IV. Sex-specific motor competence by GJH cutoff point

Cutoff	Item, total score and subscales	Mean difference		*P* value
		z-score	95% CI	
Girls				
GJH4*	Total score (Movement ABC-2)	0.23	−0.05 to 0.51	.112
	Dexterity (Movement ABC-2)	0.34	−0.04 to 0.63	**.025**
	Ball skills (Movement ABC-2)	0.05	−0.25 to 0.35	.741
	Static and dynamic balance (Movement ABC-2)	0.17	−0.09 to 0.42	.201
	Total score (BSID-II)	0.14	−0.13 to 0.41	.315
GJH5†	Total score (Movement ABC-2)	0.25	−0.07 to 0.56	.132
	Dexterity (Movement ABC-2)	0.29	−0.04 to 0.63	.087
	Ball skills (Movement ABC-2)	0.11	−0.23 to 0.45	.517
	Static and dynamic balance (Movement ABC-2)	0.21	−0.08 to 0.50	.161
	Total score (BSID-II)	0.29	−0.02 to 0.60	.063
GJH6‡	Total score (Movement ABC-2)	0.34	−0.02 to 0.70	.064
	Dexterity (Movement ABC-2)	0.33	−0.05 to 0.70	.087
	Ball skills (Movement ABC-2)	0.23	−0.15 to 0.62	.229
	Static and dynamic balance (Movement ABC-2)	0.21	−0.12 to 0.54	.216
	Total score (BSID-II)	0.14	−0.21 to 0.48	.430
Boys				
GJH4§	Total score (Movement ABC-2)	0.20	−0.05 to 0.44	.112
	Dexterity (Movement ABC-2)	0.28	0.04 to 0.52	**.025**
	Ball skills (Movement ABC-2)	0.04	−0.20 to 0.28	.741
	Static and dynamic balance (Movement ABC-2)	0.18	−0.10 to 0.45	.201
	Total score (BSID-II)	0.14	−0.13 to 0.40	.315
GJH5¶	Total score (Movement ABC-2)	0.21	−0.06 to 0.48	.132
	Dexterity (Movement ABC-2)	0.24	−0.04 to 0.52	.087
	Ball skills (Movement ABC-2)	0.09	−0.18 to 0.36	.517
	Static and dynamic balance (Movement ABC-2)	0.16	−0.09 to 0.53	.161
	Total score (BSID-II)	0.29	−0.02 to 0.59	.063
GJH6**	Total score (Movement ABC-2)	0.29	−0.02 to 0.60	.064
	Dexterity (Movement ABC-2)	0.27	−0.04 to 0.58	.087
	Ball skills (Movement ABC-2)	0.19	−0.11 to 0.49	.229
	Static and dynamic balance (Movement ABC-2)	0.22	−0.13 to 0.57	.216
	Total score (BSID-II)	0.14	−0.02 to 0.49	.430

P values in bold type are statistically significant ($P < .05$).
*Subjects (non-GJH/GJH): 138 (79/59).
†Subjects (non-GJH/GJH): 138 (97/41).
‡Subjects (non-GJH/GJH): 138 (109/29).
§Subjects (non-GJH/GJH): 111 (85/26).
¶Subjects (non-GJH/GJH): 111 (96/15).
**Subjects (non-GJH/GJH): 111 (99/12).

prevalence requires caution. Taking into account the distribution of hypermobile joints and the risk of development of symptoms might be of importance. A recent prospective study demonstrated that the presence of GJH represents a risk factor for musculoskeletal pain during adolescence, especially in the shoulder, knee, and ankle/foot.[37] In addition, knee symptoms are the most frequently reported symptoms by individuals with GJH.[16]

In the present study, no significant association was found between GJH and motor performance at age 5.5 years, although the results indicated higher *z*-scores (albeit nonsignificant) on motor performance in children with GJH at all 3 cutoff levels compared with children without GJH. As potential confounders, BMI and sex were taken into account owing to their documented influence on GJH and motor performance.[2,6,39,40] In addition, within the same sex, our study showed a trend toward better results in all performance areas of the Movement ABC-2 in girls and boys with GJH compared with girls and boys without GJH. This finding is in line with 2 previous comparable studies showing no association between motor performance and nonsymptomatic GJH in Caucasian children at age 8 years[2] and age 10 years,[10] along with a better performance in motor competence tests in children with GJH5 and GJH6. Furthermore, no association between GJH and motor performance was found by Jelsma et al,[23] who used the same validated, standardized, and norm-referenced tests to assess GJH and motor performance in Dutch children aged 3-16 years; however, these results are in contrast to several other studies showing dysfunctional motor development in children with GJH.[14,18-21,41-43] An explanation for this discrepancy might be the selected population, that is, children diagnosed with HMS or referred to a pediatric or rheumatology clinic.[14,21,22,43] Other previous studies did not use a valid, standardized, and norm-referenced test to assess GJH or motor performance.[19-21]

Besides the aforementioned sex differences, in the GJH4 group we also observed increased manual dexterity in both boys (on univariate analysis) and girls (on univariate and multivariate analysis). We were not able to find a theoretical explanation for this observation. Remarkably, in girls, hypermobility was present in all joints, whereas in boys, hypermobility was observed primarily in the upper extremities. In the literature, delayed motor development in children with GJH is explained mainly by proprioceptive

and muscle torque deficits[16,21,44]; however, those samples consisted of children with joint HMS and thus are not comparable with our healthy sample in the present study. The presence of pain or other clinical symptoms may play a significant role in motor performance owing to inactivity and deconditioning.[1,13]

We compared the data obtained at age 5.5 years with that obtained at age 2.0 years. To perform this analysis, we assumed that the data measured at age 5.5 years with regard to the Beighton test also applied at age 2.0 years. This assumption is supported by the literature, with Beighton scores reportedly decreasing with age.[2,11,45] Differences in outcome among GJH cutoff levels suggest that a moderate level of GJH confers a motor advantage, whereas higher levels do not. This might be related to the larger sample size of the GJH4 group, or to the fact that children with GJH6 might have more systemic involvement of collagen type I structures.[14] Importantly, in the GJH4 group, we found a significant negative effect of increasing BMI growth on the rate of development of motor performance. In a recent longitudinal study, D'Hondt et al[40] found that the evolving level of gross motor coordination over time was strongly related to children's weight status; normal-weight children showed better progress than their overweight or obese peers, who performed significantly worse. BMI growth in children with GJH appears to contribute longitudinally to poorer motor performance compared with children without GJH.

The development of musculoskeletal pain over time in children with GJH could be another risk factor for motor developmental problems. Two prospective follow-up studies identified GJH as a risk factor for musculoskeletal pain during adolescence.[12,38] A previous study also indicated that HMS commonly affects children between the ages 8 and 15 years[46]; however, the pathophysiological mechanism for this remains unknown, as does the role of GJH in the onset of complaints.[13,14] These findings do not necessary indicate that GJH is a sign of pathology, but do show that at an early age, the presence of GJH does affect motor development, but in the absence of complaints can be viewed as a variation of normality.[13,14] ■

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Table V. Sex-specific multiple linear regression for the association between GJH (yes/no) at different cutoff levels and motor performance scores (Movement ABC-2 total), in *z*-scores (SD)

Cutoff	β*	SE*	95% CI*	*P* value*
Girls				
GJH4	0.26	0.17	−0.09 to 0.60	.139
GJH5	0.24	0.19	−0.13 to 0.60	.210
GJH6	0.26	0.21	−0.16 to 0.68	.220
Boys				
GJH4	0.09	0.22	−0.36 to 0.53	.704
GJH5	0.17	0.27	−0.37 to 0.71	.527
GJH6	0.37	0.12	−0.22 to 0.96	.213

*Adjusted for height, weight, and height × weight.

Table VI. Linear mixed models comparing the influence over time of GJH at different cutoff levels on motor performance in *z*-scores (SD), measured at age 2.0 years and 5.5 years in the same cohort

Cutoff	β*	SE*	95% CI*	*P* value*
GJH4	0.86	0.39	0.09 to 1.64	.030
GJH5	0.18	0.45	−0.71 to 1.06	.688
GJH6	0.33	0.55	−0.75 to 1.42	.549

*Adjusted for covariates time, sex, BMI growth, and GJH × BMI growth.