Title:

A longitudinal study on possible correlates that might explain the onset and progression of musculoskeletal symptoms in school-aged children with Generalized Joint Hypermobility.

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This thesis is submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy in the Division of Physiotherapy,
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Declaration

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1. Ituen OA, Anieto EM, Ferguson G, Duysens J, Smits-Engelsman B. Prevalence and Demographic Distribution of Hypermobility in a Random Group of School-Aged Children in Nigeria. Healthcare (Basel). 2023 Apr 11;11(8):1092. doi: 10.3390/healthcare11081092. PMID: 37107926; PMCID: PMC10137997.
2. Ituen OA, Duysens J, Ferguson G, Smits-Engelsman B. The strength of balance: Strength and dynamic balance in children with and without hypermobility. PLoS One. 2024 Jun 26;19(6):e0302218. doi: 10.1371/journal.pone.0302218. PMID: 38923950; PMCID: PMC11206839.
3. Ituen OA, Akwaowo CD, Ferguson G, Duysens J, Smits-Engelsman B. Impact of generalized joint hypermobility on quality of life and physical activity in school-aged children: a longitudinal study. BMC Musculoskeletal DOI: 10.1186/s12891-024-08259-3
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6. Anieto EM, Anieto IB, Ituen OA, Naidoo N, Ezema CI, Smits-Engelsman B. The relationship between kinaesthesia, motor performance, physical fitness and joint mobility. in children living in Nigeria. BMC Pediatr. 2023 Oct 23;23(1):526. doi: 10.1186/s12887-023-04348-9. PMID: 37872483; PMCID: PMC10591369.

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05/02/2025

Signature……. ……. ……..
Date…….

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Dedication.

I dedicate this thesis to the loving memory of my late mother, Mrs Olubunmi Balogun, who selflessly gave everything so that I could live my dream.

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To the king eternal, the invisible, the only wise God. To him be the glory forever.

Table of Contents

List of Tables....xii

List of Figures....xiv

List of Abbreviations....xv

Abstract....xvi

Chapter 1: Introduction & Literature Review....1

1.1. Background on Joint Hypermobility....1

1.2 Prevalence of JH....1

1.3 Classification of GJH....2

1.4 GJH and Musculoskeletal symptoms....4

1.5 GJH and Quality of Life (QoL)....8

1.6 Purpose of the Study....8

1.7 Study Aims....9

1.8 Research questions....9

1.9 Outline of thesis....10

Chapter 2: Prevalence and Demographic Distribution of Hypermobility in a Random Group of School-Aged Children in Nigeria....11

2.1. Preface....11

2.2. Background....13

2.3 Methods....17

2.3.1. Design....17

2.3.2 Participant description....17

2.4. Measurements....18

2.4.1. Anthropometric Measures....18

2.4.2. Joint Mobility....18

2.4.3. Goniometry....19

2.4.4 Pain scale 20
2.5. Data analysis 20
2.6. Results 21
2.6.1. Participants' data 21
2.6.2. Prevalence of GJH 21
2.6.3. Differences in Beighton classification per age, sex and BMI classification 23
2.6.4. Prevalence of localized hyper/hypomobility 26
2.6.5. Prevalence of pain 27
2.7. Discussion 28
2.7.1. Beighton at item level 28
2.7.2. Goniometry 29
2.7.3. Age 30
2.7.4. Sex 30
2.7.5. BMI 31
2.7.6. Hypermobility Spectrum Disorder 31
2.7.7. Strengths and limitations of the study 31
2.7.8 Future studies 32
2.8. Conclusion 32
2.9 References 33
Chapter 3: The Strength of Balance: Strength and Dynamic Balance in Children with and without Hypermobility 37
3.1. Preface 37
3.2 Introduction 40
3.3 Materials and Method 42
3.3.1 Subjects 42
3.3.2 Anthropometric Measures 43

3.3.3 Beighton Score 44
3.3.4 Pain Questionnaire 44
3.3.5 Functional Strength Measure (FSM) 44
3.3.6 Hand Held Dynamometer 45
3.3.7 Y-Balance 46
3.3.8 Wedges Test 46
3.4 Data analysis 47
3.5 Results 47
3.5.1 Participant demographic and anthropometric characteristics 47
3.5.2 Joint mobility 47
3.5.3 Joint hypermobility and pain 48
3.5.4 Group differences in Strength: functional (FSM), and isometric strength (HHD) 48
3.5.5 Group differences in balance and proprioception 51
3.5.6 Association between strength and balance 52
3.6 Discussion 52
3.6.1 Pain and GJH 53
3.6.2 Proprioception and GJH 54
3.6.3 Functional strength and GJH 54
3.6.4 Isometric strength and GJH 56
3.6.5 Dynamic balance and GJH 56
3.6.6 The association between strength and balance 57
3.6.7 Strengths and limitations of study 57
3.7 Conclusion 58
3.8 References 58
Chapter 4: Proprioception and its Relationship with Range of Motion in Hypermobile and Normal Mobile Children 64

4.1. Preface 64

4.2 Introduction 66

4.3 Materials and methods 67

4.3.1 Procedure 67

4.3.2 Demographic measures 68

4.3.3 Beighton Score 68

4.3.4 Experimental protocol 69

4.3.5 Wedges Test 70

4.4 Statistical analysis 71

4.5 Results 71

4.5.1 Demographic data 71

4.5.2 Joint Position Reproduction Tasks. 72

4.5.3 Main effect of group: Hypermobile versus Normal mobile 72

4.5.4 Main effect of side: Preferred /Non-Preferred 73

4.5.5 Main effect of target angle: 110^0, 90^0, 70^0, 50°. 73

4.5.6 Main effect of task: *Unilateral versus bilateral* Joint Position Reproduction tasks (UNI/BI) 74

4.5.7 Wedges 74

4.5.8 Associations between the different proprioception tests 74

4.6 Discussion 75

4.7 Conclusion 78

4.8 References 78

Chapter 5: Impact of Generalized Joint Hypermobility on Quality of Life and Physical activity in School-Aged Children: A Longitudinal Study 83

5.1. Preface 83

5.2 Introduction 86

5.3 Materials and methods 87
5.3.1 Study participants 87
5.3.2 Beighton scoring system 89
5.3.3 The Faces Pain Scale 89
5.3.4 Child Activity Limitation Interview 89
5.3.5 The Physical Activity Questionnaire for Children 89
5.3.6 Shuttle Run Test 90
5.3.7 The Pediatric Quality of Life Questionnaire 90
5.4 Data analysis 90
5.5 Results 91
5.5.1 Baseline results 91
5.5.1.4 P 92
5.5.2 Longitudinal results 94
5.6 Discussion 102
5.6 Conclusion 105
5.7 References 106
Chapter 6: Discussion & Conclusion 113
6.2. Prevalence of Joint Hypermobility. 113
6.3. GJH, Strength and Dynamic Balance. 115
6.4. GJH and Proprioception. 116
6.5. GJH and Quality of Life. 117
6.6 Strengths and Limitations of the Study. 119
6.6.1 Strengths. 119
6.6.2. Limitations. 120
6.7 Recommendations. 120

Reference 122

Appendix 130

Appendix 1: Letter of permission to the Local Government Education Authority-Uyo ... 130

Appendix 2: Letter of permission to the Head Teacher 133

Appendix 3: Parents information and consent form 136

Appendix 4: Child's and parent's background information 140

Appendix 5: Parent's declaration form 141

Appendix 6: Child's assent form 142

Appendix 7: Protocol for Beighton score 143

Appendix 8: Shuttle run test 146

Appendix 9: Hand held dynamometer placement 147

Appendix 10: The Functional Strength Measurement 149

Appendix 11: Y-Balance test 152

Appendix 12: Faces Pain Scale 154

Appendix 13: Physical Activity Questionnaire 155

Appendix 14: Child Activity Limitation Interview (questionnaire version) 158

Appendix 15: Pediatric Quality of Life Inventory 160

Appendix 16: Wedges 161

Appendix 17: Joint position reproduction test 164

Appendix 18: Outline of tests, instruments /outcomes 165

Appendix 19: Map of Uyo Local Government Area, Akwa Ibom State 166

Appendix 20: Authors' contribution 167

List of Tables

Table 1-1: The Beighton scoring system. 4

Table 2-1: Items on the Beighton scoring system 19

Table 2-2: Demographic distribution of the joint mobility groups (Beighton score range). ... 22

Table 2-3: Excess degrees of movement in the 5th fingers, elbows, and knees in children classified as normal RoM, mobile and hypermobile. 27

Table 3-1: Beighton Scoring System 41

Table 3-2: Items of the Functional Strength Measurement 45

Table 3-3: Mean (standard deviation) of the demographic and anthropometric data for the two groups of participants. 48

Table 3-4: Estimated means (corrected for age, height, and weight) for the two joint mobility groups, on functional strength and isometric strength. 50

Table 3-5: Estimated means (corrected for age, height, and weight) for the two joint mobility groups, on balance and proprioception. 51

Table 3-6: Partial correlation between Y-Balance and functional strength and isometric muscle strength 52

Table 4-1: Demographic characteristics of the participants 71

Table 4-2: Means (SE) of the errors (in degrees) for the two mobility groups of all the conditions of the joint position reproduction tasks. 72

Table 5-1: Participants' demographic and joint mobility distributions in year one. 88

Table 5-2: Baseline comparison of joint mobility (3 categories), CALI-21, PAQ-C, SRT, and PedsQL. 93

Table 5-3: Post hoc pairwise comparison of significant group effects at baseline. 91

Table 5-4: Means (SD) for the variables per mobility group and per measurement for functional difficulties (CALI21), PA (PAC-C), shuttle run test, and QoL (PedsQoL). 100

Table 5-5: Main effects of mobility group and time on the following variables: functional difficulty (CALI21), PA (PAC-C), shuttle run test score, and QoL (PedsQoL). 99

Table 5-6 : Post hoc analysis of the main effect of group on the physical activity level outcomes. 101

Table 8-1: Score Sheet for Goniometric assessment 145

Table 8-2: Diagnosis of HSD.....145

Table 8-3: Subject and HHD Position 147

Table 8-4: Score sheet for HHD 148

Table 8-5: Items of the Functional Strength Measurement (FSM).....149

List of Figures

Figure 2-1: Participant recruitment flowchart depicting the steps in the selection procedure of the children and results per the classification of the joint mobility. 18

Figure 2-2: Wong-Baker Faces Pain Rating Scale. 20

Figure 2-3: Percentage per Beighton classification for each age group. 23

Figure 2-4: Range of motion in the age groups based on goniometry. 24

Figure 2-5: Percentage of positive Beighton scores for boys and girls per item. 25

Figure 2-6: Range of motion per joint for the BMI classification groups. 26

Figure 2-7: Excess range of motion. Note, there is a large overlap in the excess range of motion in the three Beighton classification groups. 26

Figure 3-1 : Flow chart of study participants' recruitment. 43

Figure 3-2: Means Isometric knee extensor strength values and Beighton classification. 49

Figure 4-1: Means (SE) of the errors (in degrees) for the two mobility groups of all the conditions of the Joint Position Reproduction tasks. 73

Figure 5-1: Flowchart of recruitment of study participants 88

Figure 5-2: Functional difficulties over time between the joint mobility groups. 95

Figure 5-3: Physical activity levels over time between the joint mobility groups. 96

Figure 5-4: Estimated VO_2Max over time between the joint mobility groups. 97

Figure 5-5: Overall QoL over time between the joint mobility groups. 98

Figure 5-6: Physical Health QoL over time between the joint mobility groups. 99

Figure 8-1: Faces Pain Scale 154

Figure 8-2: Wedges with different height 161

Figure 8-3: Wedges of different heights 161

List of Abbreviations.

JH	Joint hypermobility
ROM	Range of Motion
HCTD	Hereditary Connective Tissue Disorders
GJH	Generalized Joint Hypermobility
JHS	Joint Hypermobility Syndrome
HSD	Hypermobility Spectrum Disorder
EDS-HT	Ehlers–Danlos Syndrome, hypermobility type
FSM	Functional Muscle Strength
DCD	Developmental Coordination Disorder
QoL	Quality of Life
EDS	Ehlers–Danlos Syndrome
MCPJs	Metacarpophalangeal joints
MTPJs	Metatarsophalangeal joints

Abstract

Background: Generalized Joint Hypermobility (GJH) is an increased joint range of motion in multiple joints. Its prevalence in the general population is usually a function of age, gender, ethnicity and Beighton score cut-off score. GJH has been documented to be beneficial to sports and activities that require flexibility. Despite this advantage, it is assumed that joint laxity distorts joint biomechanics increasing their risk of injuries and pain. This has remained inconclusive in the literature because not all children with GJH develop musculoskeletal pain. In addition, previous studies have tested proprioception, balance and strength as possible underlying factors facilitating the onset of musculoskeletal symptoms in GJH. Yet, studies using different instruments and test positions have been inconclusive about the association. In addition, the psychosocial consequence of GJH is yet to be explored.

Our study was aimed at following up on the same group of children, taking three assessments of proprioception, functional strength and dynamic balance over a period of two years and investigating how they may influence the development of musculoskeletal symptoms in school-aged children with GJH. The children's physical fitness, functional difficulties, physical activity levels and quality of life were also measured during the study period.

Methods: A prospective longitudinal study design was used. We recruited 198 children aged 6-8 years at the beginning of the study. We classified them based on their joint mobility using the Beighton scoring system with goniometry. Strength, dynamic balance, physical fitness and proprioception were assessed using the Functional Strength Measurement, Y-Balance, Shuttle run test and Wedges test, respectively. The Child Activity Limitation Interview questionnaire version 21 (CALI-21) was used to document functional difficulties; the Physical Activity questionnaire was used to evaluate the children's physical activity level, while the children's quality of life was determined using the Pediatric Quality of Life questionnaire. The Wong-Baker FACES was used to determine the participants' pain level.

Results: A total at 195 children entered the study and 69 were lost to follow-up due to relocation or change of school at the end of the study. Proprioception, strength and balance were not different between mobility groups at the end of the study. Physical activity levels between children with and without GJH were significantly different at the end of the study. The overall quality of life was not different between the mobility groups.

Conclusion: We found a high prevalence of GJH (64.7%), and the inclusion of goniometry in the Beighton scoring system provided more specific information on joint hypermobility. None of the children with joint hypermobility developed HSD. The incidence of pain among children with GJH was so low that factors (proprioception, balance, or strength) mentioned in the literature could not be used to predict the onset of musculoskeletal symptoms in GJH. Contrary to previous findings in the literature, children with GJH in our study were not different in proprioception, dynamic balance, and functional strength compared to children with normal mobility. The outcome of this longitudinal study confirms that these factors (proprioception, dynamic balance, and functional strength) do not contribute to the onset of musculoskeletal symptoms in school-aged children with GJH, thus preventing inappropriate interventions. Despite the significant decline in physical activity in children with GJH over time, they were not different from their normal mobile counterparts in functional difficulties, physical fitness and quality of life.

Chapter 1: Introduction & Literature Review.

1.1. Background on Joint Hypermobility.

Joint hypermobility (JH) is a natural phenomenon that occurs as a result of ligamentous laxity, which enables the joint to move beyond what is considered the normal range of motion (ROM) [1]. Laxity of connective tissue is primarily of genetic origin but can also be acquired through stretching exercises or trauma [2]. JH is also referred to as joint laxity, and its presence is established using the universal goniometer [3]. When JH present in multiple joints, it is referred to as generalized joint hypermobility (GJH). It has been commonly defined using the Beighton scoring system [4]. A Beighton cut-off score of ≥ 5 has commonly been used to define GJH in children [3]. JH is regarded as an inherent trait because it is one of the features of Hereditary Connective Tissue Disorders (HCTD), a genetic disorder [5,6]. People with the hereditary form of JH have an abnormality in the encoding of type I collagen, in addition to an uneven distribution ratio, between type I and type III collagen [7]. Notwithstanding, JH can also be acquired through stretching exercises, surgery or trauma [2,8,9]. Even though JH can be inherited, the degree and magnitude of joint mobility may decline with age [10,11]. In addition, there have been instances of individuals who, in their adulthood, are classified as having normal mobility, despite having a history of joint hypermobility during childhood [12,13]. This suggests that Generalized Joint Hypermobility (GJH) may not be permanent in some individuals. Whether the consequence of JH will linger, if their hypermobility resolves, is yet to be explored.

1.2 Prevalence of JH.

JH can be present in one joints (localized), hands and feet (peripheral) or multiple joints (GJH) [9]. GJH has a reported prevalence of 8.8%-64.6% among the general population [14]. Specifically, the prevalence of GJH is higher among children, females, Africans and Asians, and to a large extent, these factors determine the prevalence of GJH in a given population [9,15]. In addition, the prevalence of GJH is higher in sports that require high flexibility [16]. Interestingly, despite the prevalence of JH being higher amongst females, the differences between sexes remain minimally explored, especially in children [17,18].

1.3 Classification of GJH

There are four known physical assessment methods of GJH, namely, the Beighton, Carter and Wilkinson, Hospital del Mar, and the Rotes-Querol scoring systems [19]. In addition, there are two questionnaire assessment methods: the Five-part questionnaire (5PQ) and the Beighton Score-self- reported questionnaire (BS-self) [19]. The Carter and Wilkinson scoring system was designed in 1964 to assess joint hypermobility [20]. The joints assessed were apposition of the thumb to the forearm, dorsiflexion of the ankle, and hyperextension of the elbows, knees, and all the metacarpophalangeal joints [20]. The Beighton scoring system is a modification of the Carter and Wilkinson scoring system. The adaptations made included the assessment of the flexion of the trunk, the removal of the assessment of the dorsiflexion of the ankle, and the reduction of the assessment of the hyperextension of all the metacarpophalangeal joints, to only the hyperextension of the fifth finger, totaling a set of nine items [21]. The Hospital Del Mar criteria assesses ten items, and includes assessment of the thumb, metacarpophalangeal joints (MCPJs), metatarsophalangeal joints (MTPJs), elbows, shoulders, hip, knee, patella, ankle/feet, and an assessment for ecchymoses or easy bruising [20]. The Rotès–Quérol scoring system is commonly used in Spanish-speaking countries, and includes measurement of the cervical and lumbar spine, shoulder, hip, and MTPJs to give a total of 11 items [22]. The 5PQ contains five questions and can be used to identify historical hypermobility in adults [23]. The BS-self was designed to simplify the Beighton scoring tests. In this questionnaire, the subject is expected to report the mobility at the fifth metacarpophalangeal joint, elbows, knees, and the apposition of thumb to forearm and trunk [24].

The Rotès–Quérol scoring system and the Hospital Del Mar criteria include measurement of additional joints but have not been commonly used because they are time-consuming, thus not suitable for large epidemiological studies [20].

In this study, the Beighton scoring system and the goniometry was use to assess joint hypermobility. The Beighton scoring system is considered the gold standard in classification of GJH, because it is valid and appropriate for large epidemiological studies [25]. The scoring is based on absence or presence of hypermobility. Joint hypermobility though hypermobility enhances joint flexibility is also considered a risk for musculoskeletal symptoms [26]. Previous cross sectional have not been able to conclude on the role joint hypermobility places in the onset of symptoms. Some authors are of the opinion that beyond the presence of hypermobility,

degree of hypermobility may be a possible explanation [27]. The dichotomous scoring of Beighton does not give indication on degree of joint hypermobility, thus the need to include goniometry in this study.

The Beighton scoring system is the most commonly used assessment, as it is fast and easy to use [19,28]. It consists of five tests, four of which are bilateral, making a total obtainable score of nine (see *Table 1*) [26]. The test is scored dichotomously, that is, a score of zero (absence of hypermobility) or one (presence of hypermobility) is awarded per item from which a total score, ranging from 0 to 9, is calculated. Based on the total score, a cut off score is then used to define GJH [25]. Limitations of Beighton scoring system includes its non-consideration for age, gender, ethnicity, or historical hypermobility, which can lead to under diagnosis in certain populations [29]. The Hospital Del Mar criteria incorporate historical data, making them more adaptable. Joint flexibility naturally decreases with age, so older individuals with a history of hypermobility may score lower than they would have in their youth [30]. Athletes & Dancers develop muscle strength and control that masks hypermobility, making them appear less flexible despite having underlying joint laxity [16]. Studies suggest that ethnicity plays a role in joint flexibility, and the Beighton Score may not be equally effective across different genetic backgrounds. Women tend to have higher Beighton Scores than men, meaning that men with hypermobility might be underdiagnosed. The Beighton Score focuses on specific joints, so people with hypermobility in areas not included in the test may be overlooked.

While some authors have used a Beighton score of ≥4, others have used Beighton scores as high as ≥7 to classify GJH. The Beighton cut-off score is an important factor in the reports on the prevalence of GJH [25]. It is thus evident that the prevalence of GJH would be very high if a Beighton score of 4 is used to define hypermobility among children. As a result, Castori et al (2017) suggested that age and gender should be considered when defining GJH with the Beighton scoring system [31]. Despite the reported validity of the Beighton scoring system [32], some authors have suggested the inclusion of actual measurement with a goniometer measurement because its dichotomous scoring method only identifies GJH and does not indicate the degree of hypermobility [33]. This suggestion is further based on the assumption that the degree of excessive motion could explain the onset of musculoskeletal symptoms in some individuals with GJH [34].

Table 1-1: The Beighton scoring system.

Item number	Test	Bilateral test	Maximum score
1	Passive dorsiflexion of the fifth metacarpophalangeal joint to ≥ 90 degrees	Yes	2
2	Passive hyperextension of the elbow ≥ 10 degrees	Yes	2
3	Passive hyperextension of the knee ≥ 10 degrees	Yes	2
4	Passive apposition of the thumb to the flexor side of the forearm, while the shoulder is flexed 90 degrees, the elbow is extended, and the hand is pronated	Yes	2
5	Forward flexion of the trunk, with the knees straight, so that the hand palms rest easily on the floor	No	1
6	Total		9

1.4 GJH and Musculoskeletal symptoms

The association of GJH with musculoskeletal symptoms was first mentioned in the literature in 1967 [35]. The presence of GJH was not considered a disorder, but rather a description of joint range of motion (ROM). This was due to the advantage GJH gave persons participating in flexibility-enhanced motor activities and sports, such as swimming and gymnastics [13,36]. However, studies later emerged that individuals with GJH showed a higher risk of sustaining injuries, leading to musculoskeletal symptoms such as pain, impaired proprioception, deficits in muscle strength, poor balance and poor motor performance [9,37]. Thus, in 2017 the terminology for symptomatic GJH was changed from Joint Hypermobility Syndrome (JHS) to Hypermobility Spectrum Disorder (HSD) to make a distinction between symptomatic joint mobility without a syndrome and Ehlers–Danlos Syndrome-Hypermobility Type (EDS-HT) [31]. To date, the question regarding why some children with GJH develop musculoskeletal symptoms while others do not has remained unanswered. This is mainly because there are no clinical measures to identify individuals with uneven distribution of collagen I and III, and those at risk of developing musculoskeletal symptoms [38]. Interestingly, the majority of patients attending symptomatic rheumatology clinics, are individuals with HSD, who are usually unrecognized, even by clinicians [39]. The cost of misdiagnosis or even the impact of symptomatic JH on one's quality of life (QoL), activity limitations and participation restrictions, cannot be overlooked [25]. Moreover, the presence of musculoskeletal symptoms in individuals classified as having 'normal mobility with localized JH', is yet to be explored.

The onset of musculoskeletal (MSK) symptoms in GJH has been hypothesized to be associated with ligamentous laxity, but the evidence in the literature is inconclusive. In addition, most of the studies examining the relationship between MSK symptoms and GJH, are cross-sectional, thus making it difficult to conclude causality [40–42]. A further gap in the literature is related to the age of onset of musculoskeletal symptoms, this is pertinent, considering the high prevalence of GJH in children whose maturation is ongoing [43].

One hypothesis related to the onset of musculoskeletal symptoms is the abnormal biomechanics caused by inherent laxity of the connective tissues, thus lacking the firmness to provide structural support and stability to the joints [31]. Biomechanics refers to the relationship between the bones, joints, and muscles, and this interaction emerges in different ways in JH, compared to a typically mobile joint [44]. One key area of difference is because of the laxity of ligaments [45]. In addition, the stability that the neuromuscular system ought to provide at the joints is reported to be compromised in JH, due to its association with muscle weakness [46]. The evidence of abnormal biomechanics in GJH has been demonstrated in studies examining gait pattern, reflected as an increased knee extension in mid-stance. The clinical implication of this is the increased risk of knee osteoarthritis from the joint stress [46,47]. Taken together, the altered biomechanics in JH affect joint loading, and increases the risk of repetitive trauma, not only at the hypermobile joint but at other body sites, where biomechanical compensatory mechanisms occur [48,49].

The contention in the literature related to GJH is that joint instability will be present in hypermobility, thus increasing the risk of injuries. However, the fact that only some individuals with GJH develop musculoskeletal symptoms, has called into question the attempt to make hypermobility synonymous with instability. Another reason why the laxity of ligaments has been linked to musculoskeletal symptoms in GJH, is because of abnormal joint loading arising from the abnormal joint biomechanics. The recurrent micro and macro trauma are assumed to cause possible destruction of mechanoreceptors at the joints [31]. Mechanoreceptors are responsible for carrying proprioceptive information from the periphery to the brain, and they are located in the joints, muscles and skin [50]. Proprioception is the awareness of both the joint in space (joint position senses) and joint movement (kinesthesia) [51]. Mechanoreceptors play a significant role in proprioception, balance and motor performance [52].

Despite the link between ligamentous laxity and the destruction of mechanoreceptors, there is conflicting evidence regarding proprioceptive deficit in children with GJH [53,54]. Some studies on children with symptomatic JH have shown a proprioceptive deficit [40,55]. However, a recent cross-sectional study challenged the association between GJH and impaired proprioception. The authors associated the outcome of their study with the instrument they used to assess proprioception [53]. It has yet to be tested if school-aged children will remain asymptomatic over the years, given their joint mobility status. The conflicting evidence on proprioception can be attributed to the methodological differences in previous studies [51].

For instance, previous studies that tested proprioception, either passive or actively, reported different results [53,56]. Grob et al. (2002), also highlighted from their study that the absence of pathology in GJH can determine proprioceptive ability of an individual [51].

Proprioception has an established link with motor learning and motor control, because it provides information on limb position, joint movement, and generated force [57]. Consequently, a deficit in proprioception may lead to poor motor performance. An earlier study by Jaffe et al. (1988), reported a motor delay in infants (8-14 months) with GJH, however, a reassessment after six months showed that some of these children had normal motor functions, similar to their peers with normal mobility [58]. Some other studies have found comparable motor performance in children with GJH, and those with normal mobility [59–61]. This raises the question: *Which factors facilitated the achievement of motor function in some children with GJH that were absent in others*?

Balance is fundamentally connected to proprioception, as the awareness of one's body position in space is important in maintaining postural stability [62]. This has been demonstrated in studies that have provided intervention for proprioception and balance deficits in individuals with GJH [17,63]. For instance, in a study by Ferrell et al. (2004), patients were recruited from a hypermobility clinic who, following their participation in an 8-week home-based exercise program which included balance exercises, demonstrated a large improvement in the proprioceptive test ($p=0.006$) [63]. Children with GJH have demonstrated varying balance abilities in static and dynamic balance. In a study by Juul-Kristensen et al (2009), children with GJH performed better in static balance than their normal mobile counterparts [61]. This was not replicated in the dynamic balance test by Falkerslev et al. (2013), where children and adults

with GJH demonstrated diminished dynamic balance [64]. Recent discussions in the literature indicate a preference for testing dynamic balance over static, because of its relevance to real-life scenarios [65]. In addition, injury predictions can be made more reliably by using dynamic balance tests, thus helping with prevention in individuals with GJH, who are highly susceptible to injuries because of their joint laxity [66,67]. Despite these developments, a gap persists in the literature concerning the consequence(s) of impaired balance over time, and the development of kinesiophobia[1]. This is important since these deficits will lead to muscular deconditioning and muscle weakness [68].

Muscle strength is essential for dynamic control, because it provides the required stability and adaptability to respond to changing circumstances [69]. Even though muscle weakness has been identified as a feature of HSD, the pattern of muscle strength in children with GJH is still unclear [40]. Although isometric strength has been commonly assessed in GJH, its clinical relevance is limited, because it only partly relates to functional strength, or activities of daily living [70,71]. Juul-Kristensen et al. (2012), conducted a study on knee function (isometric and isokinetic muscle strength) in a group of children and adults with GJH. They found that while children with GJH did not have impaired knee function compared to those with normal mobility, adults with GJH did [42]. The authors recommended the need for a longitudinal study of children with GJH so that the risk of developing impaired knee function can be tracked [42]. Jindal et al. (2016) assessed isometric strength in an adult population of individuals with GJH (mean age 21years, ±1.8), and found strength differences in the males, but not in the female participants [72]. A similar outcome was documented by Jensen et al. (2013), in their study of muscle activation in children and adults with GJH. Adults with GJH had lower isometric strength when compared with their counterparts with normal mobility. However, isometric strength was not different between children with GJH and those with normal mobility [71]. The authors concluded that dynamic muscle strength should be considered in future studies. The Functional Muscle Strength (FSM), a recently developed test of muscle strength during functional activities, has been used to evaluate dynamic strength in typically developing children and children with developmental coordination disorder (DCD) but has not yet been

[1] Kinesiophobia is an irrational and debilitating fear of physical movement or activity. It can develop after a painful injury or illness. People with kinesiophobia may avoid activities that cause pain, which can lead to chronic pain and disability.

applied in children with GJH [73–75]. The FSM would be useful in detecting whether children with GJH have adequate muscle strength during functional activities [27].

1.5 GJH and Quality of Life (QoL)

Even though GJH is not considered a disorder, hypermobility with symptoms may negatively affect physical activity levels, participation and physical fitness [10]. This may not have negative consequences if intervention is provided immediately [76]. However, since the diagnosis of symptomatic GJH is still missed by clinicians, the likelihood of complications setting in and eventually affecting QOL, is higher [77]. Apart from awareness of avoiding delay of diagnosis, it is also believed that rehabilitation should not be limited to relieving symptoms but should also lead to integrating activities of daily life [78]. QoL has been widely assessed in adults and adolescents with GJH, with the majority of studies reporting poorer QoL in adults/adolescents with GJH [15,79,80]. Interestingly, the evidence regarding QoL is more focused on children with HSD than those without symptoms [25,81,82]. Even in the absence of pain, it is not known if children with GJH will experience functional difficulties that may have long-term effects on their overall QoL [83].

Despite the growing research on joint hypermobility, symptomatic GJH is still underdiagnosed, and clinicians rarely relate musculoskeletal symptoms with the presence of GJH [84]. Clarity on the factors that precipitate the onset of musculoskeletal symptoms in GJH is important, to minimize misdiagnosis, and the huge cost of rehabilitation [48,85].

1.6 Purpose of the Study.

The outcomes of this study address the gap in information about the onset and progression of musculoskeletal symptoms in children aged 6-11 years with GJH and how this might be related to underlying factors (proprioception, balance and muscle strength, physical activity). The assessment of strength using the Functional Strength Measurement in addition to the evaluation of dynamic balance using the Y-Balance test demonstrates the physical demands during activities of daily living; thus, the outcome will help us understand how asymptomatic children with GJH can effectively perform their motor functions.

1.7 Study Aims.

This PhD study has three main aims. The first aim was to determine the prevalence of joint hypermobility (localized, peripheral, and Generalized JH) among the study population.

Secondly, to determine (in the first year of study) if proprioception, balance and muscle strength were different between children with GJH and children with normal mobility and to identify which factor(s) modulated the onset of symptoms in children with GJH.

In the second and third years of the study, the aim was to determine if proprioception, muscle strength and balance were different between children with GJH and those with HSD and to identify the possible influencing factors (proprioception, strength, balance) that modulated these changes.

Lastly (in the third year of the study), to determine the association between Beighton scores, possible influencing factors, and changes over time in pain, level of physical activity, physical fitness and quality of life in school-aged children.

1.8 Research questions.

The study was conducted to answer the following research questions

1. What is the distribution of GJH, localized, and peripheral JH among the study population?
2. Will children with increased joint mobility have poor proprioception compared to children with normal mobility?
3. Will children with increased joint mobility have poor dynamic balance compared to children with normal mobility?
4. Will children with increased joint mobility have reduced strength (static & functional) compared to children with normal mobility?
5. Will the incidence of pain be higher among children with GJH compared to children with normal mobility?
6. Will there be a difference in the level of physical activity between children with increased joint mobility and their normal mobile counterparts?
7. Will children with increased joint mobility present with reduced physical fitness compared to their normal mobile counterparts?
8. Will children with increased joint mobility have lower QoL when compared to their normal mobile counterparts?
9. Will children with HSD have poorer proprioception, poor dynamic balance and reduced functional strength when compared to children with GJH?
10. Will the incidence of musculoskeletal symptoms be higher among children with GJH at the end of the study than at the start of the study?

11. Which factor(s) (proprioception, balance, or strength) will predict the onset of musculoskeletal symptoms in GJH?

1.9 Outline of thesis.

Chapter 1 provides an introduction to JH. In this chapter the literature review on joint mobility was presented, its various types and prevalence rates. In addition, the study examined the existing literature on factors that contribute to the onset of symptoms in GJH.

Chapter 2 is a publication titled 'Prevalence and Demographic Distribution of Hypermobility in a Random Group of School-Aged Children in Nigeria'. The study presents the prevalence of localized, peripheral and generalized joint hypermobility among school-aged children in Nigeria.

Chapter 3 is a publication titled 'The strength of balance: Strength and dynamic balance in children with and without hypermobility'. The study answers the question of whether children with increased joint mobility show differences in dynamic balance and strength (static and functional) compared to their normal mobile counterparts.

Chapter 4 is a publication titled 'Proprioception and its relationship with range of motion in hypermobile and normal mobile children'. The study answers the question of whether children with increased joint mobility show differences in proprioception compared to their normal mobile counterparts.

Chapter 5 is a publication titled 'Impact of generalized joint hypermobility on quality of life and physical activity in school-aged children: a longitudinal study'. The study answers the question of whether children with increased joint mobility show differences in pain, physical activities, physical fitness and QoL, compared to their counterparts with normal mobility overtime.

Chapter 6 outlines the study conclusion, strengths and limitations of the study and offers recommendations for further research and practice.

Chapter 2: Prevalence and Demographic Distribution of Hypermobility in a Random Group of School-Aged Children in Nigeria

2.1. Preface

The ability to move one's joint beyond what is considered normal range of motion is a natural trait that was first mentioned by Hippocrates, but did not gain recognition in literature until the late 19th century, when it was included in medical syndromes such as Ehlers–Danlos syndrome (EDS) and Marfan syndrome [68]. Currently, it is thought that the actual prevalence of JH in the general population may exceed the documented rates, largely because research on JH is still emerging and it is not easily recognized, even by clinicians [29].

It is well documented in the literature that the prevalence of joint hypermobility is higher among children and Africans [86]. Establishing the prevalence of joint hypermobility among Nigerian children was necessary to establish ethnic and lifestyle difference [21], studying these variations can enhance medical understanding of the genetic basis of hypermobility and its interaction with the environment [12]. Also establishing regional prevalence rates highlights ethnic differences which helps to localize interventions as appropriate [87]. Even though GJH is reported to be highly prevalent among Africans, limited research has been conducted in Nigeria and presently there is a lack of data on GJH with systemic involvement. Diagnosis and recognition of multisystemic involvement in African children may be underreported or underdiagnosed, partly due to limited access to specialized care or awareness among healthcare providers. This highlights the need for more inclusive to better understand how these conditions manifest in the African context.

An individual may have JH in a single, multiple or peripheral joint(s) [88]. However, only the prevalence of JH in multiple joints is referred to as GJH. The reason the majority of previous research focused only on GJH is not known, but it is important to report not only the prevalence of GJH but also of localized and peripheral JH because even an individual classified as normal mobile may have localized or peripheral JH, and later manifest musculoskeletal symptoms.

The Beighton scoring system has been commonly used to classify GJH, and it has been validated in children [32]. However, for more details on the degree of hypermobility, especially for follow-up purposes, the inclusion of a goniometer will be important [89].

In the publication presented in this chapter, the prevalence of GJH in school-aged Nigerian children is reported. Ethical approval was obtained from the Faculty of Health Sciences Human Research Ethics Committees of the University of Cape Town (HREC REF: 306/2021) and the University of Uyo Teaching Hospital (REF: UUTH/AD/S/96/VOL/XXI/524).

The researcher approached the principals of each school. Permission was obtained from the school head to distribute the information and consent form to the parents of the selected children, the study included children aged 6-9 years. The information letter contained details of the study, the contacts of the candidate and the supervisory team for the parents who would require further clarification.

Prior to this, only a single study conducted on the prevalence of GJH in Nigeria (90). The study population comprised of adults and children, and a Beighton score of ≥4 was used to classify GJH. It has been pointed out in the literature that the Beighton score cut-off is one of the factors that determine the prevalence of GJH in a general population [91]. Importantly, we also evaluated the prevalence of peripheral and localized JH, a component that is scarce in the literature. In addition, we provide GJH distribution across age and gender.

The prevalence rate as reported in this publication fills the gap on localized hypermobility, GJH and peripheral joint hypermobility. Filling this knowledge gap is important because emphasis in literature has been mainly on GJH, meanwhile, risk of injury and subsequent development of musculoskeletal symptoms can occur in any hypermobile joint [33].

Even though the Beighton scoring system has been commonly used to identify GJH, its dichotomous scoring pattern has made it difficult for previous studies to establish a causal relationship between GJH and the onset of musculoskeletal symptoms [28]. In this longitudinal study, goniometry was included to increase the sensitivity of the Beighton scoring system and provide a trajectory for future studies.

healthcare

MDPI

Article

Prevalence and Demographic Distribution of Hypermobility in a Random Group of School-Aged Children in Nigeria

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Abstract: Background: The purpose of this study was to determine the prevalence of hypermobility in randomly selected healthy children, without previous trauma or disease process affecting the joints and whether other demographic variables (age, sex, BMI) had an impact on Beighton scores and range of motion (RoM) in children between 6 and 10 years of age. Results: 286 children were included; 27.3% of them had a Beighton score ≥7/9 and 72% would be classified hypermobile if we had used a Beighton cut-off score ≥4/9. Prevalence declined with increasing age. Girls were more often hypermobile (34%) than boys (20%) and this was mainly caused by increased RoM in the knees. Positive scores of finger items of the Beighton were more common than on the other items, leading to a high prevalence of peripheral hypermobility. Localized hypermobility was only found in the fifth MCP joint. A total of 15% of the children with normal mobility reached 20 excess degrees RoM of the left and right fifth MCP. Pain was present in 12 of the 239 children but was not linked to the level of mobility. Conclusion: Hypermobility is the rule in this pain-free population of children with GJH.

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Keywords: joint hypermobility; range of motion; Beighton score; prevalence; school-aged children; localized hypermobility; generalized joint hypermobility; hypermobility spectrum disorder

2.2. Background

Joint hypermobility is a condition characterized by excessive passive and/or active range of motion of the joints beyond normal limits along physiological axes [1]. This excess movement could be peripheral (limited to the hands and feet), localized (involving a single joint) or

generalized (involving multiple joints), referred to as Peripheral, Localized and Generalized Joint Hypermobility (GJH), respectively [2,3]. Joint hypermobility is predominately genetic in nature but can also be a consequence of trauma, malnutrition, or exercise [4,5]. Several tools have been used to identify hypermobility, but the most frequently used tool has been the Beighton scoring system [6].

Unlike GJH, localized and peripheral joint hypermobility have been scarcely reported in literature. The prevalence of GJH varies between 8.8% and 64.6% taking age, gender, ethnicity and Beighton score cut–off into consideration [8-10]. According to Castori and Hakim, generalized hypermobility may be observed in the joints of 2–34% of males and 6–57% of females [10]. De Boer et al. used Beighton score cut off-of >4, >5, or >6 to identify GJH in a population of 245 Dutch children and reported varying prevalence of 34.1%, 22.5%, 16.5%, respectively [11]. Also, a study conducted among 303 Arab school-aged children identified 15.2 % and 7.6% of the study population as hypermobile using a Beighton cut off of ≥ 4 and ≥ 6, respectively [12].

Two university-based studies carried out in Turkey and the United States of America reported the prevalence of localized joint hypermobility in their studies as 21.5% and 57.5%, respectively [13,14]. In addition, the Turkish study reported the prevalence of peripheral hypermobility in their study as 4.2% [13]. While it is believed that peripheral hypermobility is commoner in children, we are not aware of any study on the localized or peripheral hypermobility in children.

The influence of ethnicity, sex, and age on the prevalence of GJH has been described in two narrative literature reviews [15, 16]. According to these reviews, GJH is most prevalent in infants but decreases fast during childhood and slower during adulthood; Caucasians have shown a trend of a lower prevalence of GJH than Africans, Asians, and Arabians and females a higher prevalence of GJH as opposed to males [15, 16]. Interestingly, some studies have found no gender difference in the prevalence of GJH [3, 9].

The Beighton scoring system was modified by Beighton and Horan and has been used to identify GJH [17]. The Beighton scoring system has been most frequently used in epidemiological studies because it is easy to perform [10, 18]. However, its use as a diagnostic tool is under consideration as it lacks a consensus-based cut-off [16, 19]. The British Society of Rheumatology recommended a cut-off of ≥4 and this has been commonly used to define

GJH followed by a cut off score of ≥5 [19]. In their study of 1845 Swedish children, Jansson et al. observed that a Beighton score cut-off of ≥4 for all ages and gender will result in an overrepresentation of GJH especially among young children and females [20]. In a recent study by Singh et. al., they found a 60% false positive rate of GJH through a logistic regression analysis supporting the fact that there is a high likelihood of misclassifying young children and females as hypermobile when Beighton score cut of ≥ 4 is used to identify GJH [19]. Recently, the International Consortium on the Ehlers-Danlos Syndrome reached a consensus on an age-based Beighton score cut offs, ≥ 6 for pre-pubertal children and adolescents, ≥ 5 for pubertal males and females up to the age of 50, and ≥ 4 for those > 50 years of age [21].

Furthermore, the dichotomous pattern of the Beighton scoring system only shows the presence or absence of hypermobility and not the severity of the excess movement at the joint [3,19]. Although not all hypermobile joints are unstable, previous authors have linked laxity of ligaments and joint instability, to subsequent onset of musculoskeletal symptoms such as pain, dislocation or neurodevelopmental problems such as poor motor coordination and motor delay in GJH [2, 10]. Considering the fact that there are various degrees of excess movement in individuals with GJH, the question remains what amount of excess movement is a precursor to the development of musculoskeletal symptoms [6, 20]. That is, will individuals with higher degrees (e.g., 20 degrees) of hyperextension show a higher risk of developing symptoms compared to those with lower degrees (e.g., 10 degrees) of hyperextension? Jelsma et al. argued that the inclusion of goniometric measurement of the joints to the Beighton scoring system will give an objective identification of hypermobility and possible explanation for development of musculoskeletal symptoms later in life [22].

Joint hypermobility provides flexibility that facilitates excellent motor performance as demonstrated by gymnasts and ballerinas. A study of elite sportsmen by Schmidt et al. demonstrated a higher prevalence of GJH among the ballerinas (68.2%), than handball players (13.2%) [23]. Despite this benefit, approximately 3.3% of women and 0.6% of men with GJH develop musculoskeletal symptoms later in life [24]. When GJH becomes associated with musculoskeletal symptoms it is referred to as Hypermobility Spectrum Disorder (HSD) [2]. The diagnosis of HSD has been frequently missed or delayed due to paucity of information regarding its etiology [25, 26]. Therefore, an effective method of identifying children with GJH and those who are susceptible to developing musculoskeletal symptoms is needed so that interventional approaches can be tailored early, thereby preventing complications [27].

Even though literature has given attention to GJH over the years less is known about Local Joint Hypermobility (LJH). Two studies have reported a higher prevalence of LJH than GJH in adult populations; also one of the studies reported a higher frequency of injury among the participants with LJH [14, 28]. What is still not known is if prevalence of LJH and its association with musculoskeletal symptoms will show the same trend in children.

Although it has been established in literature that in general females are more mobile than males, evidence on gender differences on the different Beighton items has not been conclusive in previous studies [9, 12, 20, 29]. The inclusion of hands-on-floor as a joint hypermobility test has been debated, as it is highly influenced by training [30]. In addition, the trunk, pelvis and lower limbs are considered a dynamic structure with associated functions, such that tightness of hamstrings can limit trunk flexibility [31, 32]. A study involving 400 school-aged children reported that 86% of children with GJH (Beighton cut-off of ≥ 5) could not perform the hands-on-floor maneuver [7]. The study further concluded that the hands-on-floor maneuver has a very low sensitivity (13.84%) in identifying GJH and that it does not have an additional value in the Beighton score [7].

Although the Beighton scoring system was first used to evaluate the prevalence of GJH in a South African population of children [17], there is a paucity of data on the prevalence of GJH among Nigerian children. Therefore, this study targeted at exploring the following research questions;

1. What is the prevalence of PJH, LJH, GJH and HSD among Nigerian children and is this prevalence different for age, sex, and body mass index (BMI) classification groups and how does it relate to prevalence in other countries?

2. Which specific items of the Beighton scoring system are the most frequent in contributing to the classification of hypermobility and which ones the least?

3. What is the degree of the excess movement in the 5th fingers, elbows, and knees in children classified as normal RoM, mobile and hypermobile?

The inclusion of goniometric RoM of the joints in this study provides additional value to the Beighton criteria in identifying joint hypermobility. This may help identify individuals within the upper limit of joint hypermobility, thus improving both the sensitivity and specificity of the Beighton scoring system. In addition, it may also provide insight on whether the various excess

degrees of movement increase the risk of developing musculoskeletal symptoms in a group of individuals with GJH.

2.3 Methods

2.3.1. Design

The study used a cross-sectional analytical design.

2.3.2 Participant description

Study participants were recruited from 11 schools in the Southern part of Nigeria through convenience sampling. The study included children in grades 1-4 between the ages of 6-11 years. All parents of the children of the selected classes were given information and consent forms. Only children whose parents gave informed consent and children who gave assent were included in the study. Any child with recent musculoskeletal injury, or physical disability as reported by parent or medical doctor was excluded from the study (see flow chart in Figure 1). Children who reported with febrile illness on day of assessment were tested after recovery. To check for eligibility, the parents gave background information on the child's health status and completed the child physical activity readiness questionnaire (PARQ) [33]. A total of 445 children were potentially eligible for inclusion, however, the parents of 159 children did not provide consent in time. Therefore, these children were excluded from the study leaving a total 286 children who participated in the study (see flow chart in Figure 2-1).

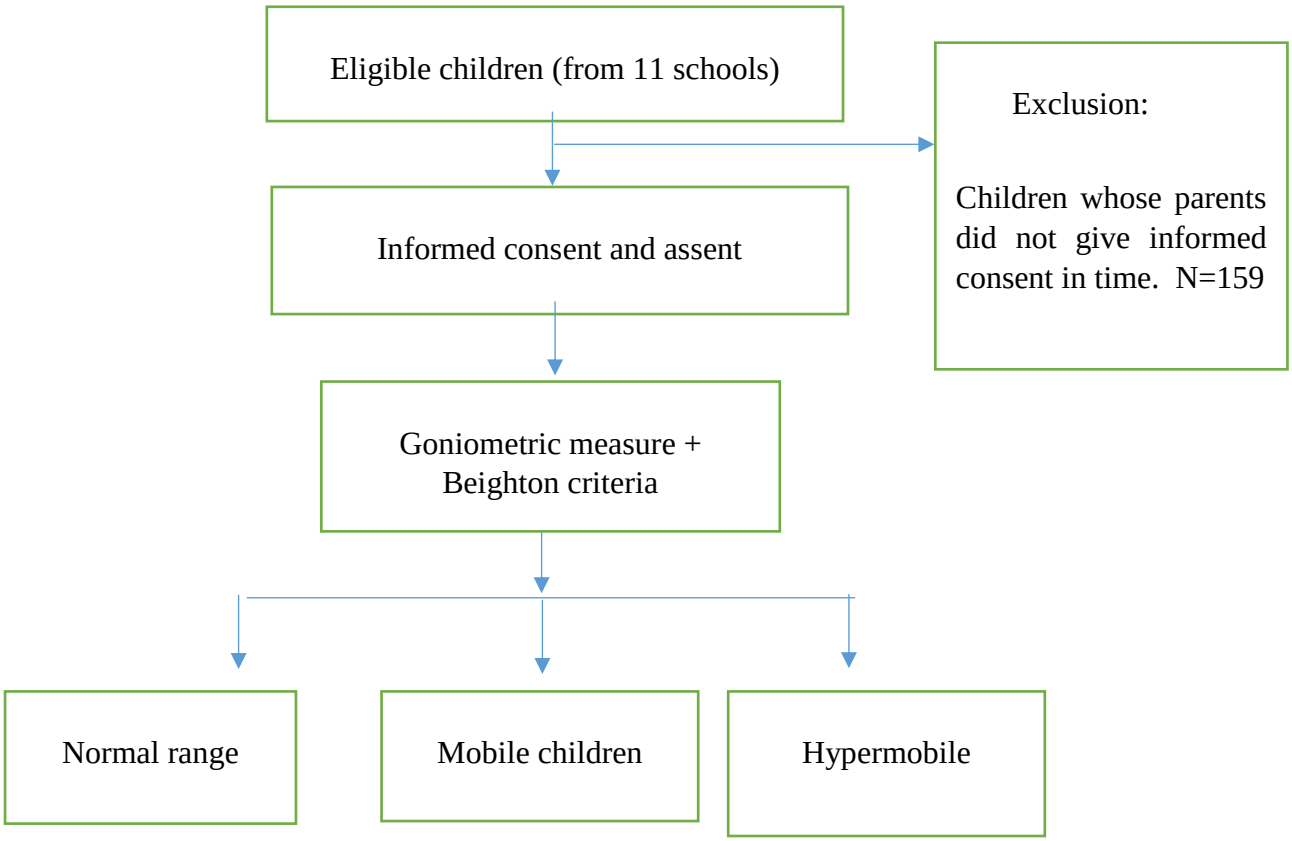

Figure 2-1: Participant recruitment flowchart depicting the steps in the selection procedure of the children and results per the classification of the joint mobility.

2.4. Measurements

2.4.1. Anthropometric Measures

We collected data on participants' age (years), sex, height (centimeters), and weight (kilograms). Height and weight were measured using measuring tape and weighing scale (on bare feet; measured to the closest one cm and 100 g, respectively). The body mass index (BMI) calculation was performed using the age-gender specific BMI centiles recommended by the WHO [34]. The BMI centile classifications are: Underweight= ≤ 2nd centile, Normal weight= 3rd to 90th centiles, Overweight= 91st to 97th centiles, Obese= ≥ 98 centile.

2.4.2. Joint Mobility

Joint hypermobility was classified based on the scoring system developed by Beighton et al. [17]. The test consists of four passive range of motion (RoM) items (assessed bilaterally) and one active forward flexion task (Table 2-1). The Beighton scale has a 9-point maximum score

based on the degree of movement of the 5th metacarpophalangeal (MCP), elbow, knee joints, thumb movement, and the mobility of the spine. Participants were awarded one point for a positive test, and a total numerical score of 0 to 9. Although the Beighton test has not been formally evaluated for its psychometric properties in the Nigerian population, it is considered as a valid test of joint mobility in children [3], which was shown by comparing the Beighton scale to the goniometry of 16 passive ranges of motion of joints on both sides of the body. Joint mobility was categorized based of the total Beighton score obtained. The 9 points Beighton score can be divided into 3 main categories (category I Normo-mobile = 0 to 4 points; category II Mobile = 5 to 6 points; category III Hypermobile = 7 to 9 points) with the highest category representing participants with the greatest joint hyper-mobility. Normo-mobile, Mobile, and Hypermobile categories represent participants who had normal joint mobility, moderate hypermobility, and generalized joint hypermobility, respectively.

Table 2-1: Beighton scoring system

Items	Right	Left
a. Passive opposition of the thumb to the volar side of the forearm	1	1
b. Passive dorsiflexion of the 5th MCP joint to $\geq 90^0$	1	1
c. Passive hyperextension of the elbow joint to $\geq 10^0$	1	1
d. Passive hyperextension of the knee joint to $\geq 10^0$	1	1
e. Placing hands flat on the floor with the knees kept straight		1
Maximum possible score		**9**

2.4.3. Goniometry

Additionally, joint range of motion of the 5th MCP joint extension, elbow joint hyperextension, and knee joint extension was assessed to the nearest 1-degree using the standardized joint mobility protocol [3]. A standard 2-legged 360-degree type Collehon extendable goniometer (Lafayette Instrument Company, Lafayette, IN, USA) was used for the knees and elbow and a small arm goniometer for the 5th MCP. Joints were measured bilaterally.

2.4.4 Pain scale

To examine pain, participants were asked to choose the face of the Wong-Baker Faces Pain Scale (FPS) that best reflected the intensity of the pain they were experiencing [35]. The FPS (Figure 2-2) is a self-report pain scale that uses facial expressions to assess the intensity of pain. It is a valid instrument and has been used to assess pain among Nigerian children with sickle cell anemia [36].

Figure 2-2: Wong-Baker Faces Pain Rating Scale.

2.5. Data analysis

Data was analyzed using the SPSS version 28. Descriptive statistics (frequency, percentage, mean, and standard deviation) were used to present the demographic data, Beighton scores, RoM and Beighton classification of the study population. The univariate ANOVA was used to test for differences between the three joint mobility groups, in age and BMI classification. Because of the lower numbers of participants in the 10- and 11-year-old bracket, these data were combined for the age analysis. The children in the overweight and obese categories were also combined because of their low numbers.

To evaluate differences in frequency of Beighton items and RoM between age groups, sex and BMI classification groups, standard tests of significance were applied. Pearson Chi-square tests were used to test if the prevalence of positive and negative Beighton items was different for age group, sex and BMI classification.

For the goniometry, paired t-test was used for the comparison between RoM for left and right side and independent t-test for gender differences. Lastly, ANOVA was used to test if RoM was different for age and BMI classification groups. Degrees greater than the Beighton criteria, extension for elbow and knee (≥ 10) and 5th MCP (≥ 90), were designated as "excess degrees of motion". Alpha was set at 0.05 for a 95% confidence level.

2.6. Results

2.6.1. Participants' data

The study included a total of 286 children, 138 males (48.3%) and 148 females (51.7%). Mean age 7.7 (SD 1.2). Of the children 99.3% were right-handed. Mean BMI was 15.34 (SD 3.0). Almost half the children (49.3%) classified within the normal range of weight for their age and sex, 38.8 % was underweight. Overweight and obese accounted for 8.4 and 3.5%, respectively. Demographic data are shown in Table 2-2.

2.6.2. Prevalence of GJH

The mean Beighton score was 5.35 (SD 1.77). Joint mobility, classified based on the total Beighton score, yielded 35.3% children as normo-mobile (score 0-4), 37.4% as mobile (score 5-6) and 27.3% as hypermobile (score 7-9). Demographic data per joint mobility group are shown in Table 2-2.

Table 2-2: Demographic distribution of the joint mobility groups (Beighton score range).

	Normo-mobile (Beighton 0-4) N (%)	Mobile (Beighton 5-6) N (%)	Hypermobile (Beighton 7-9) N (%)	Test value, p- value
Age years				X^2 27.34,p 0.007
6	11 (22.9)	14 (29.2)	13 (47.9)	
7	28 (35.4)	31 (39.2)	20 (25.3)	
8	28 (31.8)	35 (39.8)	25 (28.4)	
9	15 (36.6)	17 (41.5)	9 (22)	
10/11	19 (63.3)	10 (33.3)	1 (3.3)	
Mean (age)	8.03 (1.28)	7.79 (1.15)	7.29 (1.06)	F 8.96, p 0.001
Gender				
Male	57 (41.3)	53 (38.4)	28 (20.3)	$X^2$7.55, 0.023
Female	44 (29.7)	54 (36.5)	50 (33.8)	
BMI class				$X^2$3.45, 0.485
Underweight	35 (31.5)	40 (36)	36 (32.4)	
Normal	53 (37.6)	56 (39.7)	32 (22.7)	
weight	13 (38.2)	11 (32.4)	10 (29.4)	
Overweight	15.86	15.16 (2.79)	14.93	
Mean BMI	(3.35)		(2.93)	F 2.36. 0.097

N=Number of children per classification; (%) percentage of children per classification; BMI class=BMI classification. Alpha was set at 0.05.

If we examine the frequency of the dichotomous classification (negative/normal range or positive/hypermobile) per item, the 5th MCP joints had the highest frequency of positive scores in both males and females (98.3%; see figure 2-5).

Goniometry showed that the overall excess range of motion was larger on the left side than on the right side of the body ($t(1,285)=4.52$, $p<0.001$). The means of the passive RoM of the 5th MCP (right =7.40 degrees (SD 7.96), left=8.42 degrees (SD 7.88); $t(1,285)=5.67$, $p<0.001$), elbow (right =0.44 degrees (SD 4.12), left=0.91 degrees (SD 4.12); $t(1,285)=2.90$, $p=0.004$), were higher on the left side and not different for the knees (right = -2.11 degrees, left=-2.07 degrees; $p= 0.77$).

2.6.3. Differences in Beighton classification per age, sex and BMI classification

Details of the age, sex and BMI differences on the Beighton classification are presented in Table 2-2.

Age: Hypermobility was less frequent in older children (X^2= 27.34, p= 0.007; see Figure 2-3). The mean Beighton score decreased with age (F(4,281)=7.77, p <0.001). Frequency of positive scores over age groups was not different for the item hands on floor.

Based on the measured range of motion, there was a significant effect of age for all joints except for the left knee (p=0.14; see Figure 2-4). However, some fluctuations were seen between adjacent age groups for the MCP5 joints.

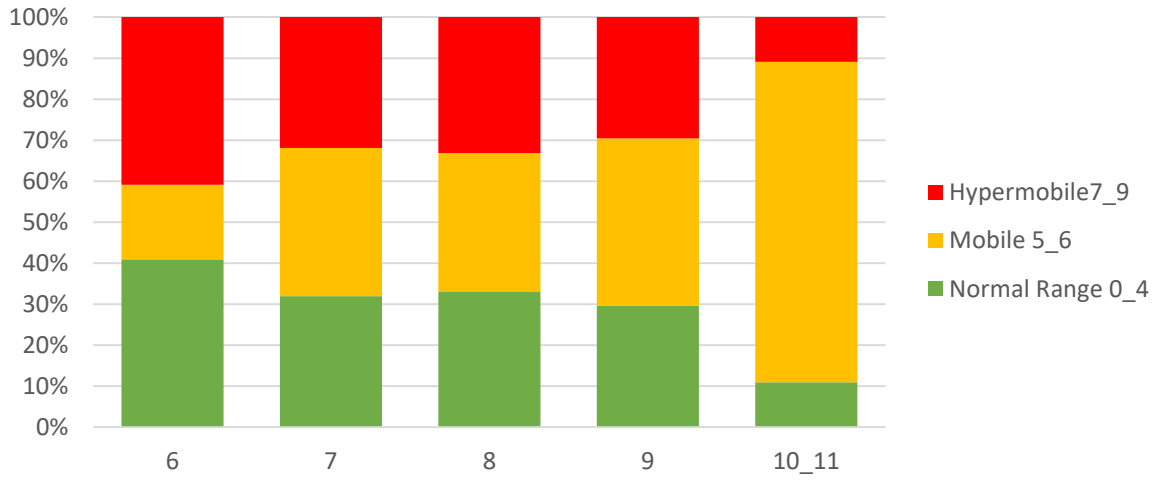

Figure 2-3: Percentage per Beighton classification for each age group.

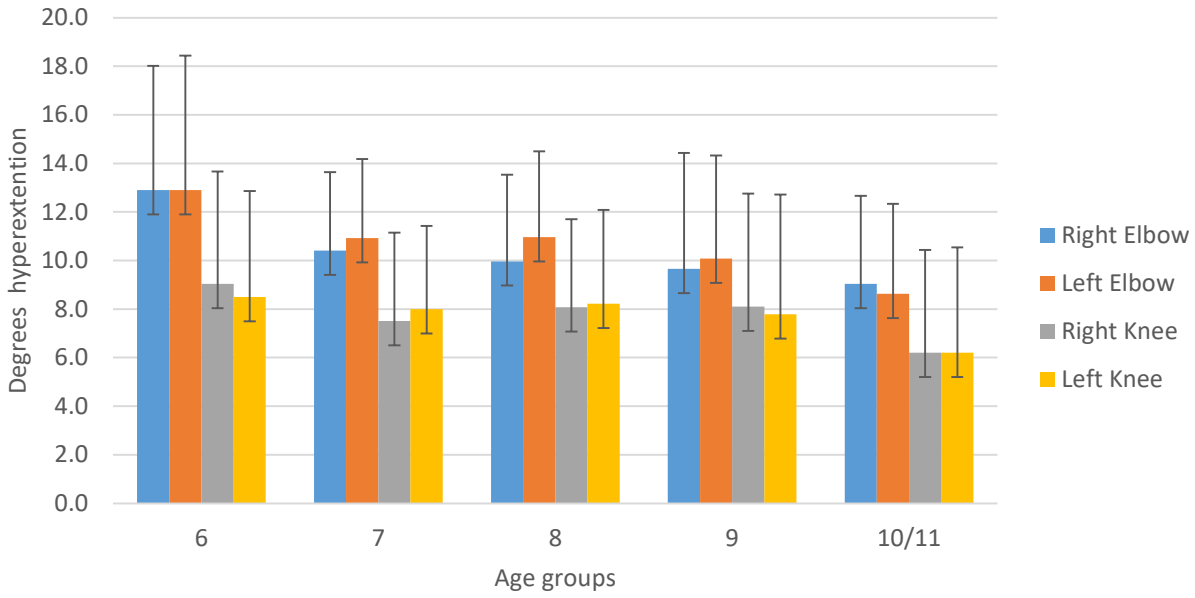

Figure 2-4: Range of motion in the age groups based on goniometry. Error bars depict the standard deviation

Sex: The mean total Beighton score was 5.04 (SD1.67) and 5.64 (SD1.82) for boys and girls, respectively (t(1,284)=-2.94, p=0.004). Of the girls in our sample, 34% were classified hypermobile (score 7-9) while this was 20% for the boys. Females were more often rated hypermobile on the different Beighton items and the chi-square showed a higher frequency of positive scores for the left elbow (X^2=5.98. p=0.015), and left (X^2= 11.22, p=0.001) and right knee (X^2= 7.91, p=0.006). One item showed a trend in the opposite direction; Boys were more often (16.7%) able to put the hands flat on the ground than the girls (9.5%; X^2= 3.29. p=0.08) (Figure 2-5).

Based on the measured degrees of RoM, there was a significant effect of gender for the knees (right (t(1,284)=-2.06, p=0.04); left (t(1,284)=-3.26, p=0.001) and not for the MCP5 and elbows.

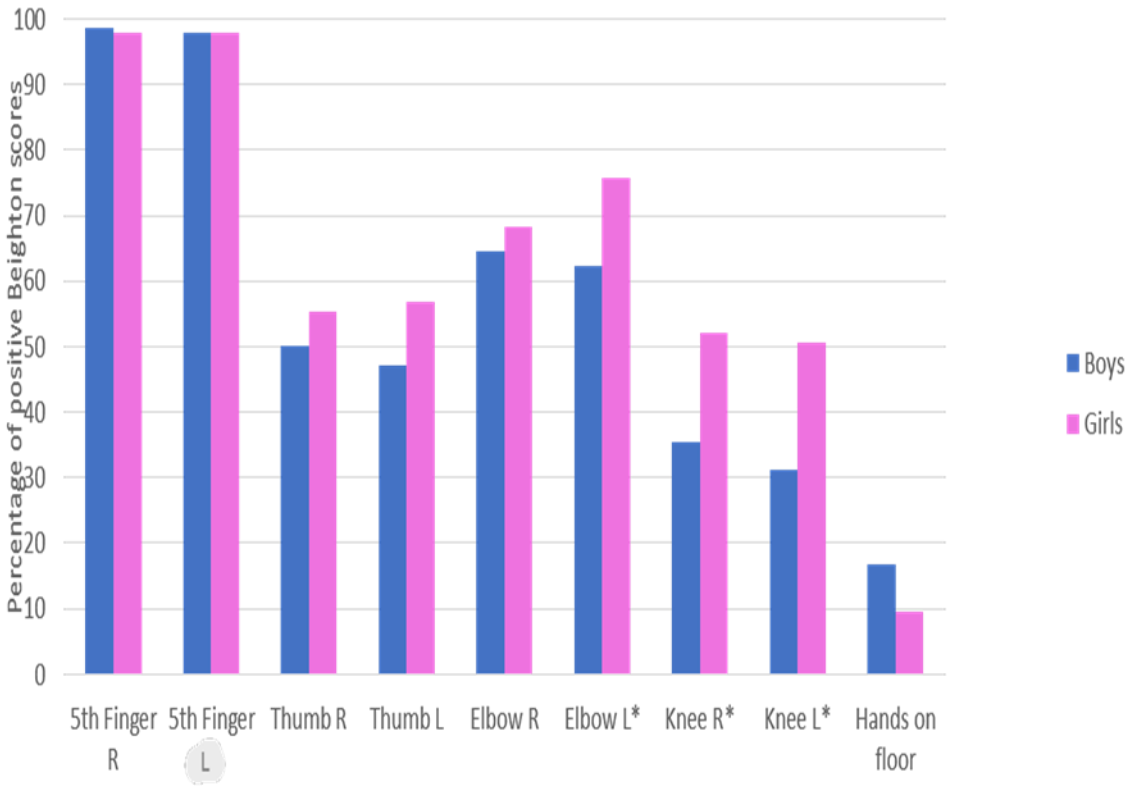

Figure 2-5: Percentage of positive Beighton scores for boys and girls per item. * indicates significant differences.

BMI: Differences emerged in Beighton scores between BMI classification groups, but the pattern of differences was not comparable between joints. Frequencies of positive scores were different for knee (X^2= 8.54, p= 0.014) and thumb item on the right (X^2= 8.68, p= 0.013). Goniometry showed that all except one joint were different (elbow right; p=0.21) for the BMI classification groups (all < p 0.02), however the direction differed per joint (Figure 2-6). The little fingers showed a larger RoM in obese/overweight children, while the knees were more mobile in underweight children. The elbows were the least mobile in the normal weight children.

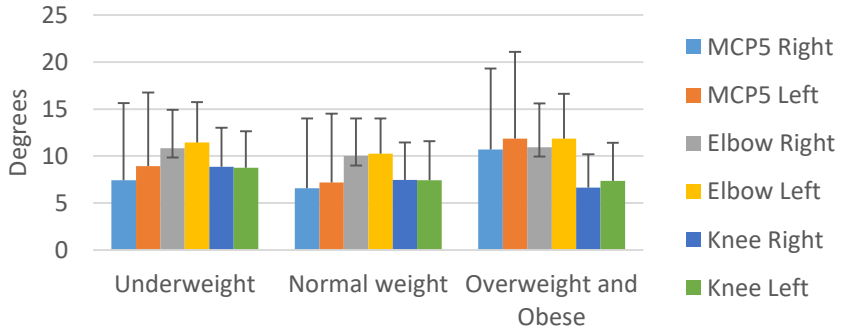

Figure 2-6: Range of motion per joint for the BMI classification groups.

2.6.4. Prevalence of localized hyper/hypomobility

Peripheral hypermobility defined as at least 3 positive items in the hands in normo-mobile children occurred in 12.9%. None of the normo-mobile children scored positive on all 4 hand items.

Localized hypermobility was defined as 10 degrees more RoM than a positive Beighton score in normo-mobile children. Out of 101 children with normal mobility as defined by the total Beighton score, 15 (14.9%) could move further than a 100-degree angle in the left and right 5th MCP joint. No other joint had an excess RoM in children with normal mobility.
Major joint hypermobility defined as 10 degrees more RoM than a positive Beighton score in at least 3 joints (elbows and knees) was absent in the normo-mobile group. Out of the 185 children classified as hypermobile, 3 (3.6%) had 20 degrees RoM hyperextension in the right elbow joint and 5 (6.4%) in the left elbow joint. One mobile child had a hyperextension of more than 20 degrees in the left knee, none of the mobile and hypermobile children had 20 degree or more hyperextension in the knee joints.

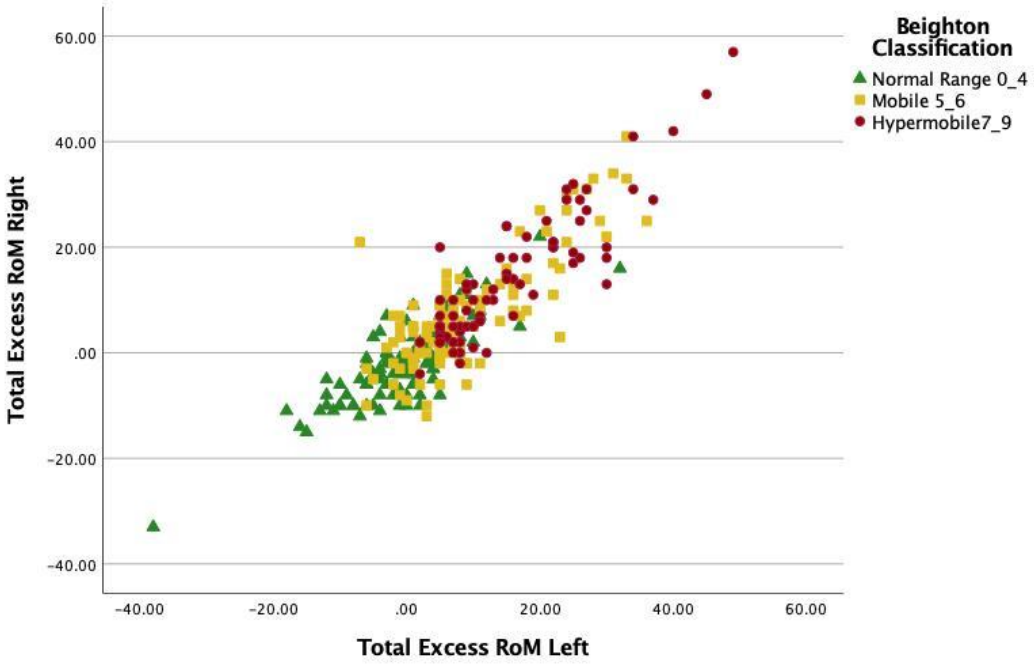

Figure 2-7: Excess range of motion. Note, there is a large overlap in the excess range of motion in the three Beighton classification groups.

Table 2-3: Excess degrees of movement in the 5th fingers, elbows, and knees in children classified as normal RoM, mobile and hypermobile.

Beighton Classification	Excess RoM Right Mean (range) in degrees	Excess RoM Left Mean (range) in degrees
Normal Range (n=101)	-2.3 (-33 - 22)	-0.78 (-38 - 32)
Mobile (n=107)	7.3 (-12 - 41)	8.9 (-7 - 36)
Hyper Mobile (n=78)	14.0 (-4 - 57)	15.4 (2 - 49)

Excess RoM is defined as degrees greater than the Beighton criteria, which for extension for elbows and knees, is more than 10 degrees and for 5th MCPs more than 90 degrees. The excess degrees of motion in children classified as normal RoM, mobile and hypermobile is summarized in Table 2-3 and Figure 2-7. Excess range of motion is significantly different between mobility groups for all joints, as are post hoc comparisons (all $p<0.001$) except for comparison between the mobile and hypermobile group for the MCP5 joints. As shown in Figure 7, there is a large overlap in Beighton classification groups for children with the same excess range of motion. Some children in the mobile group have large excess of motion but located in only a few joints, or in case of normal mobile children even in fewer joints.

Hypomobility: All children reached full extension in the knee and elbow joints (at least 0 degrees). Five (1.7%) children did not reach 90 degrees extension in the right 5th MCP and 6 (2.1%) in the left 5th MCP. One child had low flexibility in all joints measured.

2.6.5. Prevalence of pain

Responses to the pain questionnaires were available for 239 children. A total of 94.1% of the children reported no pain, 8 children marked the face indicating “hurts a little bit” (3.3%; 3 normal, 2 mobile, 3 hypermobile), 6 children rated their pain as “hurts even more” (2.5%), none of them were hypermobile, 4 normo-mobile, 2 mobile.

2.7. Discussion

The first aim of the study was to describe the prevalence of Generalized Joint Hypermobility, Peripheral, Localized and Hypermobility Spectrum Disorder among Nigerian children. As there is no universal agreement on a threshold for hypermobility, we used three cut-off scores to define joint mobility classifications: Normal Range (score 0-4), Mobile Range (score 5-6) and Hypermobile Range (score 7-9). Using this classification 35.3% of the children classified as Normal-mobile, 37.4% as Mobile and 27.3% as Hypermobile. If we use a total Beighton score of ≥5 as cut off for hypermobility, a prevalence of 64.7% would be established. The higher prevalence seen in this study compared to previous studies may be due to two reasons: first ethnicity and second the age range [37-39].

The high frequency of GJH in our present study is supported by a study of an Australian population that included Caucasians and non-Caucasians (Africans, Asians, and indigenous Australians). Hypermobility was significantly lower in the Caucasian group [19]. Interestingly, Morris et al carried out a study in an Australian population and reported a prevalence rate of GJH that was 28.8% higher than a similar group in the United Kingdom [40]. Reuter and Fichthorn in their study of 654 American University students did not report a significant difference in the prevalence of GJH among the different ethnic groups and concluded that the influence of ethnicity needs future research [14].

In this study we also presented the prevalence of Peripheral (17%) and Localized hypermobility (15%). Localized hypermobility was very rare, and only occurred in the finger joints. It is interesting to note that 15 children, though classified as normo-mobile, had an excess ROM of 20 degrees of the 5th MCP (right and left), while only three children classified as hypermobile had an excess of 20 degrees ROM of the 5th MCP (right and left).

2.7.1. Beighton at item level

The analysis on item level of the Beighton scoring system showed that the 5th MCP joints had the highest frequency of hypermobility (98.3%) and largely contributed to percentages of children classified as hypermobile. This finding is consistent with previous studies where frequency of hypermobility is higher in the upper limbs than the lower limbs [12, 40, 41]. If only the larger joints (Major Joint Hypermobility: knee and elbow) would be used to classify hypermobility in our study, the percentage would go down to about 39%. The hands-on-floor

item has consistently shown a trend of least positive scores in previous studies in children and our finding was not different, neither was it age related [6, 41]. The atypical finding in our study was the higher frequency of boys having a positive score compared to girls on this item. Typically, children in our age bracket find it difficult to place their palms on the floor because they are at the stage when the growth rate of their lower limbs is higher than the trunk and upper limb lengths [8]. Thus, the hands-on-floor item might give different results in adulthood. Interestingly, in an earlier study among a Nigerian population (a setting of peasant farmers and traders) aged 6-66 years, hands on floor had the highest frequency of hypermobility on the Beighton items [37]. Their study had a large age range but did not report the age at which the trunk flexibility started to increase. The habitual posture of bending over is common among farmers, may have helped to stretch the hamstrings over time. Previous authors have questioned the inclusion of 'hands-on-floor' in the Beighton items as this test is not solely based on laxity of ligaments but also hamstring extension and the individual's growth stage [8]. In addition, the dynamic relationship between the thorax, trunk and lower limbs makes it impossible to treat their functions in isolation [38]. Interestingly, the study by Czaprowski et al., reported no difference in pelvic-hip muscles and trunk flexibility in children with and without GJH [32]. A consideration for future studies is to evaluate the suggested association between lumbopelvic control and risk of injury in the lower limbs, as this may provide justification for the inclusion of the hands-on-floor in the Beighton test [32].

2.7.2. Goniometry

Because the Beighton scale gives no indication of the degree of hypermobility we also used goniometry to measure the RoM of the MCP5, elbow and knees, as we have shown this to be a valid way of measuring hypermobility [3]. By doing so we could show large overlap in the additional range of motion in the 6 joints measured in the 3 mobility classification groups. In theory, a child classified as Normal-mobile with 2 mobile joints (e.g. 2 times 15 degrees hyperextension knees) could have more excess RoM as another child classified as Hypermobile with 6 times 1 degree additional hyperextension in knee, elbows and little finger above the Beighton criteria. Especially for follow-up studies, goniometry may be more sensitive than a dichotomous scaled item and might show higher relation with the development of musculoskeletal complaints. Malek et al. argued that localized hypermobility may even have a higher risk of becoming symptomatic than GJH [6]. In the present study, we also showed that

the overall excess range of motion was significantly larger on the left side than on the right side of the body. Our sample population was predominantly right-handed making the left side non-dominant. This is in line with our previous study in Dutch children [3].

2.7.3. Age

The inclusion of 6 years old children will have increased the frequency of hypermobility, which corroborates with earlier findings [6, 12, 19]. Our study found a significant decrease of mean Beighton score with age. The hypermobile group had the lowest mean age (7.29 years) while the normal mobile group had the highest mean age (8.03 years). When goniometry outcomes were compared, we found a significant effect of age for all the joints except for the left knee.

2.7.4. Sex

In this study, the prevalence of GJH was significantly higher among females. This is in line with previous evidence in literature [42,43]. Based on the dichotomous classification of the items, females had a significantly higher frequency of positive scores for the left elbow ($p=0.015$), right knee ($p=0.006$) and left knee ($p=0.001$). If we used goniometry, gender differences were only found for the knee joints. This is an important finding as it might be related to development to symptoms later in life [43]. Especially, in combination with increased valgus angles more often seen in females than in males [44].

Interestingly, on the hands-on-floor test, males had a higher frequency of positive score in this test, although the difference was not significant ($p=0.08$). Even though literature has widely supported higher frequency of GJH among females than males due to hormonal influence, the evidence has been inconclusive and may again depend on age and cut off values used. Studies by Smits-Engelsman et al. and Juul-Kristensen et al., included children between ages 6-12 years and both studies did not find an association between GJH and gender [3,39]. The studies by Singh et al. and Morris et al. included adolescents, and both reported significant association between gender and GHJ [19, 40]. In the study by Sirajudeen et al., the prevalence of GJH was not significantly different between genders; however, females were more hypermobile in their thumb and elbow, the males were more hypermobile in their knee and trunk [12].

2.7.5. BMI

In most developing nations, obesity is rapidly becoming a serious health issue but, in our sample, a third of the children were underweight. We examined weight as a risk factor for increased joint movement and likelihood for (later) complaints. The present study found that the hypermobile group had the highest number of underweight children (<5th percentile). We also found a significant difference between positive scores for hypermobility and BMI groups for the knees and right thumb items. Interestingly, goniometry showed an opposite trend in range of motion and BMI classification for 5th MCP joint and the knee; little fingers were more mobile while the knees were the least mobile in overweight/obese children. Although BMI is assumed to have an influence on GJH, the findings in literature on their association have not been conclusive. In the study by Clinch et al., on 6022 children the relationship between BMI and GJH was found among obese girls who were 2.47 times more likely to be classified as hypermobile [41]. In the study by Sirajudeen et al. the association between BMI and GJH was found among females with lesser BMI score [12]. A recent study showed the impact of under nutrition on muscular power and agility [45]. The combination of large RoM in the knees and lower muscle power may make the children with underweight more prone to injuries.

2.7.6. Hypermobility Spectrum Disorder

Clinically, a higher frequency of pain exists in hypermobile children compared to normal mobile [2], however this was not found in our sample. None of the children was classified as having Hypermobility Spectrum Disorder according to our assessments. Hypermobile children did not report pain; in fact, hardly any pain was reported in this random population.

2.7.7. Strengths and limitations of the study

The inclusion of goniometric RoM of the joints in this study provides additional value to the Beighton criteria in identifying joint hypermobility. This may help identify individuals within the upper limit of joint hypermobility, thus improving both the sensitivity and specificity of the Beighton scoring system. It may be a more sensitive way of determining the severity of joint hypermobility other than the previously used dichotomous scale. In addition, it may also provide insight in whether the various excess degrees of movement increase the risk of developing musculoskeletal symptoms in a group of individuals with GJH.

Our study included a large number of Nigerian children, however, it is important to replicate the study in other African and Western countries, to be able to generalize the findings.

2.7.8 Future studies

Previous studies have tried to establish a causal relationship between GJH and the onset of musculoskeletal symptoms without a consideration for the largeness of excess degree of motion; this needs to be pursued in new studies. Also, the question remains to be answered if individuals, who are classified as normal mobile but with localized hypermobile joints, will develop symptoms.

2.8. Conclusion

This was the first study to describe the prevalence of all three classifications of asymptomatic joint hypermobility (PJH, LJH, GJH) and HSD in school aged children. Although a prevalence of 64.7% hypermobility is high (cut off ≥5), we did not find any children with Hypermobility Spectrum Disorder. If this will change when children grow older will be the topic of our longitudinal study. Our findings extend previous observations that the item hand-on-floor gives divergent results; it is the only item with a low frequency in hypermobile children, not sensitive to age and showed a trend to be more frequent in boys than girls.

Taken together we concluded that in this age bracket, hypermobility is more the rule than the exception. It is often based on excessive RoM in the finger joints (58%). Also, the mobility changes with age. Differences between genders in the RoM in our sample follow the described patterns in the literature. Goniometry instead of dichotomous rating of the joints will provide more sensitive information. Clinically, this may be important to study the development of musculoskeletal complaints later in life. The criteria for defining GJH in any given population will determine its prevalence. Consensus on Beighton score cut off values as appropriate for age, gender and ethnicity are urgently needed. A minimum requirement for all studies reporting on hypermobility is that the cut off values are mentioned.

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Chapter 3: The Strength of Balance: Strength and Dynamic Balance in Children with and without Hypermobility

3.1. Preface

GJH enhances flexibility in activities, but not without the risk of injuries, because of its abnormal biomechanics. Muscle strength and balance are essential for motor control, thus ensuring activity participation [92]. Previous studies have attempted to answer the question of how individuals with GJH maintain control of the extra range of motion during activities, and how to prevent musculoskeletal complications [27]. Muscle weakness has been associated with hypermobility spectrum disorder (symptomatic GJH), but the evidence in literature regarding the association between strength and balance in children with GJH, is limited and inconclusive [10,42,72,80].

Even though muscle strength can be evaluated in both static and functional conditions, it is known that the interpretation of functional strength is more relevant to real-life scenarios [68]. Isometric muscle strength has been evaluated more frequently in children with GJH, thus we presented both forms of muscle strength evaluation. In addition, poor balance has been identified as an indicator of pathology when GJH becomes symptomatic [9]. Strength is important in maintaining stability (balance), especially where there is an extra range of motion to control and the evidence for this is still limited in literature [69,71]. In order to identify children who may develop musculoskeletal symptoms, we tested for strength and balance. We compared the outcome between children with GJH and those with normal mobility in our study population. Our test of balance was done using the Y-balance test, a dynamic and demanding test [69,93].

Apart from the biomechanical abnormality of GJH, it is assumed that the risk of injury may also be modulated by impaired strength and poor balance [65]. Previous studies that have reported deficits in strength and balance of children with GJH were done in static conditions, making it difficult to relate to real-life scenarios because injuries are more likely to occur in dynamic rather than static conditions. In this present study, a dynamic balance assessment (the Y-Balance test) diverged from previous studies that used the one-leg stance despite its ceiling effect. In addition, the strength of participants in this study was assessed using the Functional

Strength Measurement. This study will add new insights into functional strength and dynamic balance in the study of children with GJH.

Additionally, Han et al. (2016) in their review of the literature recommended that tests of proprioception should be performed in functional positions as this offers a representation of how proprioception functions during activities of daily living. The wedge test in conducted in standing, unlike other proprioceptive tests which are conducted in open-chain positions. Another reason for choosing to use the Wedge test is that it is a simple and cheap instrument that has demonstrated ecological validity, making it ideal for large epidemiological study [53].

PLOS ONE

RESEARCH ARTICLE

The strength of balance: Strength and dynamic balance in children with and without hypermobility

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Abstract

Background

Generalized Joint hypermobility (GJH) is predominantly non-symptomatic. In fact, individuals with joint flexibility usually perform better than their non-hypermobile counterparts during physical activities. Notwithstanding, strength and balance are essential to maintain the control of the extra range of motion during activities and to prevent musculoskeletal complications. There are limited and conflicting pieces of evidence in literature regarding the association between strength and balance in children with GJH.

Objectives

The purpose of this study was to examine differences in functional strength, dynamic balance, proprioception, and isometric strength in children with and without joint hypermobility and determine the association between strength outcomes and dynamic balance.

Method

A cross-sectional study was conducted among children aged 6 to 11. Hypermobility was determined using the Beighton Score, with scores ≥6 representing hypermobility. Functional strength was assessed with the Functional Strength Measure (FSM), isometric strength was determined with a handheld dynamometer (HHD), the Y-Balance Test (YBT) was used to assess dynamic balance and the Wedges test to measure proprioception.

Results

This study included 588 participants (age: 7.97 ± 1.3 years; height: 128±10.1 cm; mass: 27.18 ± 7.98 kg). 402 children were classified as having normal mobility and 186 as being hypermobile. Hypermobile children had better functional strength in the lower extremities than children with normal range mobility but lower reach distance in the YBT. No differences in proprioception, functional strength of the upper extremity or isometric strength in the hands were found. However, isometric lower extremity force was less in hypermobile

3.2 Introduction

Generalized Joint hypermobility (GJH) a result of laxity of ligaments, is commonly examined with the Beighton score, and its prevalence usually depends on age, gender and ethnicity [1, 2]. GJH is typically of genetic origin but may also be acquired through exercises, stretching or trauma [3, 4]. Although GJH enhances activities that require flexibility, it also poses risk for complications, specifically musculoskeletal symptoms [5-7]. The initial assumption by previous authors has been that a hypermobile joint is unstable, predisposing it to repetitive micro-traumas that destroy mechanoreceptors over time [8,9]. This will lead to joint injury, arthralgia and other complications, such as compromised proprioception, impaired strength, and poor balance [10,11]. When GJH becomes associated with the aforementioned musculoskeletal symptoms it is referred to as Hypermobility Spectrum disorder (HSD) [12] . Even though GJH is a risk for developing musculoskeletal symptoms, biomarkers and clinical predictors of musculoskeletal symptoms are highly variable [13-15]. It is interesting that hypermobility is inherently more prevalent in children who are biologically immature when the growth of the musculoskeletal system is ongoing [13, 16]. It remains a question to be answered if children with GJH will be more prone to micro trauma, because they are less coordinated or have less muscle power to adapt to sudden balance disturbances [17]. This raises the suggestion that immature muscle strength plays a role in GJH.

Strength and balance are important in the context of pathology [18]]. They are essential for many daily and leisure activities, and it is assumed that a deficit of either will have a negative impact on an individual's participation levels [19]. Muscular fitness is a synergy of the different components of muscle activities (muscle strength, power and endurance) whereby multiple muscle groups work together in a coordinated way across a range of joint angles and, depending on the activity, for different periods [20-22]. Muscular strength is the maximum amount of force one can produce or the amount of weight one can lift [23] whereas, explosive power is the ability to generate a maximum muscular contraction instantly in a burst of movement [24]. On the other hand, the ability to repeat a movement for an extended period without fatiguing is muscle endurance [25, 26]. Isometric strength is tested by a muscle contraction against maximum resistance over one joint in one direction with the rest of the body in a stabilized position [27]. Lastly, the strength needed to perform fundamental motor skills is called functional strength [26]. Yet, muscle strength in individuals with hypermobility has been mostly evaluated under isometric conditions, while functional strength may be more relevant

for daily activities [28, 29]. Hence, the need to reevaluate the relationship between strength and GJH, as a greater functional strength compensates for the ligament laxity [30].

Balance is defined as the ability to maintain an upright posture and to keep the center of gravity within the limits of the base of support [31]. Muscle strength and proprioception have been reported to play significant roles in balance [32]. The most frequently used test to assess balance clinically in children with GJH is one leg stance [5, 33]. Although, this test is sensitive in assessing balance, it is a static test and it also lacks task difficulty thus creating a ceiling effect [31,34]. In addition, testing balance dynamically is more appropriate because the need to keep your center of gravity within your limits of stability in order to prevent injuries is higher during functional activities than in quiet standing [35, 36]. The Y-balance test, (standing on one leg and reaching forward as far as possible with the other leg) is a good alternative to the static one leg stance test as it induces large shifts in center of pressure unlike the small anticipatory shifts seen in static balance control [19]. Most importantly, the stability boundaries encountered during the reaching movement with the foot are very different from stationary upright one-leg standing making this task more challenging and less sensitive to a ceiling effect [35].

There are two possible routes for the onset of musculoskeletal symptoms in children with GJH [32]. First, stabilizing a joint during physical activities requires strength but when strength is compromised in a hypermobile joint, the possibility of sustaining injury is increased [37]. In another view, laxity of ligament or capsule may degrade the proprioceptive information from a hypermobile joint which may lead to delayed stabilization of the loaded joint inducing further damage of mechanoreceptors at the joint and this results in pain [38].

To disentangle this problem, the first step is to evaluate children with hypermobile joints before they have developed limiting musculoskeletal complaints and study if their proprioception, strength and balance are different from children with normal mobile joints. Next, one needs to examine the relationship between these outcomes and performance in a loaded dynamic balance task, imitating natural conditions. In our planned research, we will follow up on these children to see how many develop musculoskeletal complaints and which variable(s) predict the later development of these complaints.

In this study, we will answer the following research questions:

1) Are functional strength, dynamic balance, proprioception, or isometric strength diminished in a random sample of children with joint hypermobility between 6-11 years of age compared to children with normal range of joint motion?
2) How strong is the relationship between strength and balance in children between 6-11 years of age?

3.3 Materials and Method

3.3.1 Subjects

The study used a cross-sectional descriptive design. The study was conducted following the Declaration of Helsinki. Ethical approval was obtained both from the human research ethics committee of the University of Cape Town (UCT HREC: 096/2015, HREC REF: 306/2021) and the University of Uyo Teaching Hospital REF: UUTH/AD/S/96/VOL/ XXI/524.The secretary of the Local Government education-Uyo, and the Anambra State Universal Basic Education Board Chairman, along with the head teachers and class teachers at the selected schools all granted permission to assess the children. Schools were selected through the convenience sampling method. The recruitment period was from 20th September 2021- 31st October 2021. The following exclusion criteria were applied: i) Children who have high risk level and poor safety as it pertains to physical activity, this was assessed using The Physical Activity Readiness Questionnaire (PAR-Q) for children ii) Children who were limited in their ability to understand the testing instructions or the performance of the activities (e.g., cognitive impairment, gross motor impairment etc.) as reported by parents [39]. None of the children were excluded using the above criteria. The study sample size was calculated through a power analysis that showed that a total sample size of 164 per group was needed for a medium effect size (d= 0.4), at a power of 95%, while alpha is set at 0.05 with and allocation ratio of 1. The G-power analysis software version 3.1.9.2 was used for the sample size calculation [40]. Written informed consent was obtained from the parents or legal guardians of the children, and assent was given by the children before their enrolment. The children were tested by trained researchers in their school. The children were given breaks between tests or as requested by the child.

588 children were recruited, 186 were hypermobile. Children who reported with febrile illness on day of assessment were tested after recovery. Some of our study participants were not tested on Y-Balance (equipment was not available at the site at time of testing) and HHD (faulty equipment at the time of assessment). Halfway during the testing period, we observed the need to improve the sensitivity of the Wedges test and thus included additional wedges to achieve this (see flow chart in Figure 3-1). Only data with the more sensitive wedge test were included.

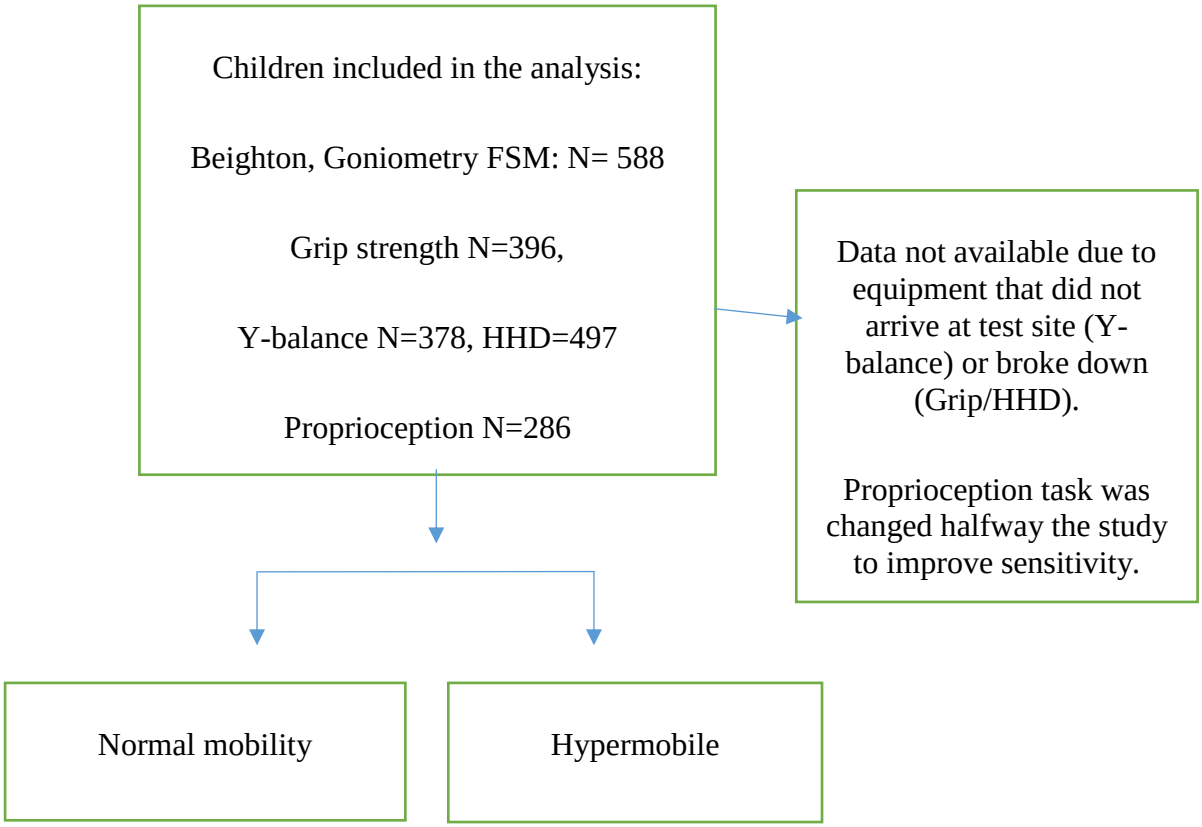

Figure 3-1 : Flow chart of study participants' recruitment.

3.3.2 Anthropometric Measures

Data were collected on participants' age (years), sex, height (centimeters), and weight (kilograms). Height and weight were measured using measuring tape and weighing scale (on bare feet; measured to the closest one cm and 100 g, respectively). The body mass index (BMI) calculation was performed using a metric formula, weight (in kilograms) divided by height (in

meters squared). Children were classified in Under-, Normal- and Overweight/Obese based on WHO norms for-age-and- sex [41].

3.3.3 Beighton Score

The nine-point Beighton score, with goniometry, was used to assess joint mobility [42]. The Beighton scoring system consists of bilateral assessment of the 5th metacarpophalangeal (MCP), elbow, knee joints, thumb movement and one active forward flexion task (Table 3-1). A score of 0-9 was used to divide joint mobility into two categories, normal mobility (0-5) and hypermobility (6-9) [43]. We established GJH with a Beighton score of ≥6. The test has been validated among children [44].

Table 3-1 : Beighton Scoring System

Items	Right	Left
a. Passive opposition of the thumb to the volar side of the forearm	1	1
b. Passive dorsiflexion of the 5th MCP joint to ≥ 90^0	1	1
c. Passive hyperextension of the elbow joint to ≥ 10^0	1	1
d. Passive hyperextension of the knee joint to ≥ 10^0	1	1
e. Placing hands flat on the floor with the knees kept straight	1	
Maximum possible score	9	

3.3.4 Pain Questionnaire

The pain intensity was rated using Wong-Baker Faces Pain Scale (FPS) [45]. The FPS is a self-report pain scale that uses facial expressions to assess the intensity of pain. It is a valid instrument and has been frequently used to evaluate pain intensity in children [46, 47].

3.3.5 Functional Strength Measure (FSM)

The FSM is a comprehensive norm-referenced test for assessing functional strength in an activity [26]. The FSM test items comprise of two sets of four items in each set (upper limbs and lower limbs with four items in each set) [20]. There are the muscle power tests (e.g.,

standing long jump, overarm throwing) and muscle endurance tests (e.g., sit to stand, lifting a box). For items description see Table 3-2. The FSM has been validated among different groups of children and satisfactory values of test retest reliability of 0.91-0.94 were found [26].

Table 3-2: Items of the Functional Strength Measurement

Items of the FSM	**Item description**
Overarm throwing (cm)	Throwing a heavy bag as far as possible.
Standing long jump (cm)	Jumping forwards as far as possible.
Underarm throwing (cm)	Throwing a heavy bag as far as possible.
Chest pass (cm)	Pushing a heavy bag as far as possible.
Lateral step up (# in 30 s) Tested on right and left	Touch the foot to the floor as fast as possible while standing on one leg on the lowest step of the stairs.
Sit to stand (# in 30 s)	Stand up and sit down as quickly as possible.
Lifting a box (# in 30 s)	Lift a plastic box filled with heavy bags onto a wooden box
Stair climbing (# in 30 s)	Climbing up and down stairs as quickly as possible

3.3.6 Hand Held Dynamometer

The Hand-Held Dynamometer (HHD) was used to assess maximum isometric muscle contraction of the knee extensors, ankle extensors and flexors and grip strength [48]. To measure the isometric strength of the knee extensors, the participants were seated in a table with the knees at 90^0 of flexion and the HHD placed on the anterior surface of the leg. The plantar flexors and dorsiflexors, were assessed in supine position, the HHD was placed on the sole of the foot to test for plantar flexors and the dorsum of the foot to test for dorsiflexors. The break method was used and the best of three trials was used for the analysis [20]. The HHD is

a reliable instrument that has been used in children with ICC values ranging from 0.73 to 0.99 [49].

3.3.7 Y-Balance

The Y-balance test was developed as a time efficient test to replace the Star Excursion Balance Test (SEBT) [50]. It assesses dynamic stability in three directions (anterior, posteromedial, and posterolateral) instead of eight as was the case in SEBT. The test kit consists of a platform for stance and three pipes connected to the stance platform. The subject to be tested stands on the stance platform and uses the other limb to move the reach indicator along the calibrated pipe. The distance reached (measured in centimeters) is recorded. The Y-Balance test is considered effective in predicting injuries [51]. The Y-Balance test has demonstrated an excellent interrater reliability within session (ICC > 0.995) and between sessions ($0.907 \leq ICC \leq 0.974$) among children [19]. The test is performed three times and the best of the three is normalized with body height or limb length because of their reported correlation [52]. Limb length was not collected at all schools, while height was, hence we tested the relation between normalized distance using limb length and by using height for the 195 children for which we had both. Results showed correlations between normalized distances calculated based on limb length or height to be 0.93 both for right and left leg. This confirmed that it was valid to use normalization with height for all children in our analysis.

3.3.8 Wedges Test

We tested proprioception (detection of heel-height difference) using the wedges of various heights that produce different angles equal in surface, 1.5°, 3°, .4.5°, 6°, 9° and 12°. The 1.5°, 4.5° wedges were added to have more combinations with only 1.5° difference (1.5° versus 3°, 3° versus 4.5°, 4.5° versus 6°).

Wedges demonstrated ecological validity in a study that measured proprioception among 7-10 years old Nigerian children with GJH [53]. Tools that have ecological validity can show the role proprioception plays in physical activities [54].

Participants stood behind a table and were not blindfolded during the testing but were instructed to not look at their feet while the test was conducted. While standing on the wedges, (without support from the table) they raised the arm of the side with the higher ankle. For example, the right arm for the right ankle. Both arms were raised when no difference in ankle-

height was detected. The subject had 5 seconds to respond. A penalty score was awarded to every incorrect response, and it was determined by differences in the height of the wedges. The higher the wedges height difference, the higher the penalty score. The individual penalty scores were summed up to get a total penalty; a high penalty score indicates poor proprioception

3.4 Data analysis

Data was analyzed using the SPSS version 28. Descriptive statistics (frequency, percentage, mean, and standard deviation) were used to present the demographic data, Beighton scores, and Beighton classification of the study population. FSM, HHD, Y-balance and Wedges data were checked for outliers using histograms and z-score. Data points with z-values of more than 3.29 were deleted. No more than 3 data points per variable were removed. Because of the large differences on demographic variables between the normal and hypermobile children, all tests were adjusted for age, weight, and height. As a next step, Box test of equality of covariance matrixes was examined and found significant; thus, Pillai's Trace will be reported. No violation of linearity between the dependent variables and covariates was found. Seven multivariate analyses of covariance (MANCOVA) were conducted with Beighton classification group as independent variable, and functional strength of lower extremity, upper extremity, Y-balance, isometric strength knee, grip force, ankle strength and proprioception were treated as sets of dependent variables, concerning the same construct and with the same number of data entries. Two-tailed partial correlation analyses, controlling for age, were performed to verify the relationship between strength and Y-balance. Alpha was set at 0.01.

3.5 Results

3.5.1 Participant demographic and anthropometric characteristics

Our study included 588 children, 281 males and 307 females. The study mean age was 7.97 (S.D 1.3) years. Most children were normal weight (61.6%), 22.8% were underweight and 15.6% were overweight/obese.

3.5.2 Joint mobility

Of the total sample, 402 children were classified as normal mobile (male, female) and 186 children (79 male and 107 female) were classified as hypermobile. Although the two groups came from a one convenience sample (same schools, same background) the two classification

groups showed some differences. The children with hypermobility were significantly younger, smaller, and lighter (p=0.001) than the children with normal mobility (see details in Table 3-3). This was corrected for in the statistics

Table 3-3: Mean (standard deviation) of the demographic and anthropometric data for the two groups of participants.

Demography	Normal mobile	Hypermobile	p-value
N	402	186	
Age (Years)	8.2 (1.3)	7.5 (1.2)	0.001
Height (cm)	1.29 (0.1)	1.24(0.1)	0.001
Limb length (cm)	129.9 (10.2)	124.4 (8.8)	0.001
Weight (kg)	28.6 (8.34)	24.1 (6.0	0.001
BMI (kg/m^2)	16.7 (3.2)	15.4 (2.8)	0.001

N=Number of participants

3.5.3 Joint hypermobility and pain

In this random sample, 498 children reported no pain, and 90 children (71 normal mobile, 19 hypermobile) reported some pain. Of these 90, more children belonged to the normal mobile children (n=71, 78.9%) than to the group children with hypermobility (n=19, 21.1%) (X^2 = 3.15, p 0.08). However, this difference was not statistically significant. None of the children reported long term pain or pain during the testing.

3.5.4 Group differences in Strength: functional (FSM), and isometric strength (HHD)

The multivariate analysis showed that hypermobile children had better outcomes on the FSM lower extremity scores (p=0.001). The univariate analysis showed significant differences for all items except for stairs (p= 0.19). For the multivariate outcomes of the upper limb items of the FSM, no significant differences were found. Estimated means were corrected for age, weight, and height and the statistics are presented in table 3-4.

The isometric strength of the knee extensors, and ankle flexors and extensors, and grip force were measured using the HHD. The children with normal mobility had significantly higher mean values for the knee extensors (Figure 3-2), ankle extensors and ankle flexors but not for grip strength. Details of isometric strength outcomes for the two groups and statistics are presented in table 3-5.

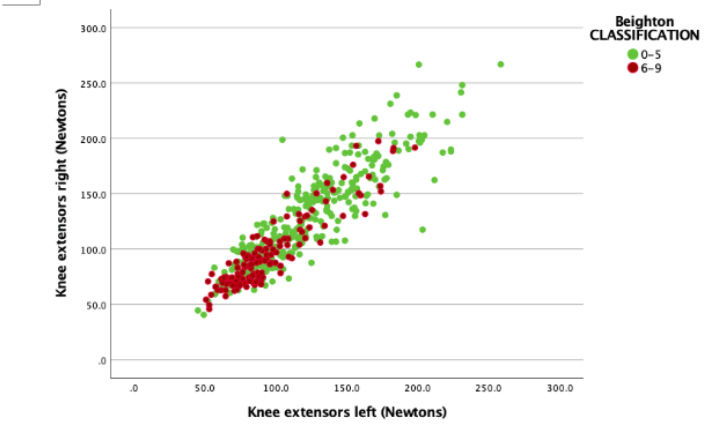

Figure 3-2: Means Isometric knee extensor strength values and Beighton classification.

Table 3-4: Estimated means (corrected for age, height, and weight) for the two joint mobility groups, on functional strength and isometric strength.

	Normal mobile Est. Mean (Std. error)	Hypermobile Est. Mean (Std. error)	F-value	P-value	Partial eta squared
FSM n=588					
MANCOVA Lower limbs					
Beighton classification[a,b,c]			7.7	0.001	0.062
Univariate					
Lower limbs					
Lat. Step up RT	37.6 (0.7)	43.6 (1.0)	22.4	0.001	0.037
Lat. Step up LT	37.8 (0.7)	43.3 (1.0)	19.6	0.001	0.033
Stair climbing	66.5 (0.5)	65.2 (0.8)	1.7	0.19	0.003
Sit to stand	24.0 (0.3)	26.7 (0.8)	18.4	0.001	0.031
Long jump	111.8 (1.3)	118.6 (1.9)	7.9	0.005	0.013
FSM n=496					
MANCOVA Upper limbs					
Beighton classification[a,b,c]			3.6	*0.001*	0.063
Univariate					
Upper limbs					
Upper hand throw	200.2 (2.7)	199.8 (3.7)	0.01	0.92	0.0001
Under hand throw	258.9 (4.2)	251.0 (5.8)	1.2	0.28	0.002
Chest pass	160.6 (2.2)	160.7 (3.0)	0.0001	0.99	0.0001
Lifting of box	16.8 (0.3)	16.4 (0.4)	0.46	0.50	0.001
HHD n=487					
MANCOVA Knee extensors					
Beighton classification[b,c]			11.7	*0.001*	0.046
Univariate					
Knee extensors RT	122.8 (1.7)	107.1 (2.7)	23.4	0.001	0.046
Knee extensors LT	117.2 (1.6)	104.5 (2.6)	17.1	0.001	0.034
HHD n=396					
MANCOVA Grip strength					
Beighton classification[a]			0.26	*0.773*	0.001
Univariate					
Grip RT	46.5 (0.8)	45.5 (1.1)	0.503	0.479	0.001
Grip LT	43.5 (0.7)	42.6 (1.1)	0.384	0.536	0.001
HHD n=287					
MANCOVA Ankle muscles					
Beighton classification[b,c]			2.9	*0.01*	0.058
Univariate					
Dorsiflexors RT	83.2 (2.0)	74.0 (2.6)	7.3	0.007	0.025
Dorsiflexors LT	85.3 (2.8)	71.3 (3.7)	8.8	0.003	0.033
Plantarflexors RT	97.2 (2.2)	87.4 (2.9)	7.1	0.008	0.025
Plantarflexors LT	98.0 (2.0)	87.5 (2.6)	9.5	0.002	0.030

Significant covariates: a=height, b=weight, c=age. RT= Right, LT=Left, n=number of participants

3.5.5 Group differences in balance and proprioception

The multivariate analysis revealed that study participants with normal mobility reached further on the Y-Balance test. Univariate analysis showed that this was the case for posteromedial and posterolateral directions, but no differences were found in anterior direction.

No differences were found between groups on the proprioception outcomes. A high penalty or low correct score on the wedges' tests indicated poor proprioception (Estimated Means and statistics are shown in table 3-5).

Table 3-5: Estimated means (corrected for age, height, and weight) for the two joint mobility groups, on balance and proprioception.

	Normal mobile Est. Mean (Std. error)	Hypermobile Est. Mean (Std. error)	F-value	P-value	Partial eta squared
Y-Balance test (n=378)					
MANCOVA Balance					
Beighton classification[a,b]			4.6	*0.001*	0.070
Univariate					
Anterior RT	39.6 (0.5)	40.1 (0.6)	0.3	0.6	0.001
Anterior LT	40.3 (0.5)	40.9 (0.6)	0.6	0.4	0.002
Posterior-medial RT	46.9 (0.6)	44.1 (0.8)	7.6	0.006	0.020
Posterior-medial LT	48.6 (0.7)	45.1 (0.8)	11.1	0.001	0.029
Posterior-lateral RT	47.9 (0.6)	44.9 (0.8)	8.5	0.004	0.023
Posterior-lateral LT	49.2 (0.7)	45.8 (0.8)	9.7	0.002	0.026
Proprioception n=286					
MANCOVA Wedges					
Beighton classification			0.9	*0.42*	0.006
Univariate					
Total penalty score#	4.1 (0.4)	3.4 (0.4)	1.8	0.183	0.006
Total correct score	18.6 (0.2)	18.8 (0.2)	1.0	0.328	0.004

Significant covariates: a=height, b=weight. RT= Right, LT=Left, n=number of participants.

3.5.6 Association between strength and balance

Partial correlation, controlled for age, was performed and moderate partial correlations were found between the Y-balance mean score and FSM strength throw outcomes of the Upper extremity and isometric strength of knee and ankle muscles (Table 3-6). No significant correlations were found between the lower extremity items: long jump and sit to stand and Y-balance total score.

Table 3-6: Partial correlation between Y-Balance and functional strength and isometric muscle strength

	Total Beighton r (p)	Mean Normalized Y-Balance r (p)	Normalized Y-Balance Right r (p)	Normalized Y-balance Left r (p)
FSM n=588				
Lower limbs				
Lat. Step up RT	0.223 ***	0.157 **	0.167 ***	0.141**
Lat. Step up LT	0.223 ***	0.160 **	0.168 ***	0.144**
Stair climbing	-0.150 ***	0.256 ***	0.238 ***	0.263***
Sit to stand	0.238 ***	ns	ns	ns
Long jump	0.214 ***	ns	ns	ns
FSM n=496				
Upper limbs				
Upper hand throw	ns	0.359 ***	0.341***	0.362***
Under hand throw	ns	0.366 ***	0.345***	0.371***
Chest pass	ns	0.165 **	0.168**	0.156**
Lifting of box	ns	0.175 **	0.18 **	0.158**
HHD n=487				
Knee extensors				
Knee extensors RT	-0.418 ***	0.342 ***	0.300 ***	0.364 ***
Knee extensors LT	-0.372 ***	0.259 ***	0.226 ***	0.275 ***
HHD n=396				
Grip strength				
Grip RT	-0.1*	ns	ns	ns
Grip LT	ns	ns	ns	ns
HHD n=287				
Dorsiflexors RT	-0.402 ***	0.402 ***	0.373 ***	0.408 ***
Dorsiflexors LT	-0.434 ***	0.418 ***	0.382 ***	0.429 ***
Plantar flexors RT	-0.344 ***	0.303 ***	0.274 ***	0.313 ***
Plantar flexors LT	-0.330 ***	0.335 ***	0.312 ***	0.338 ***

***Correlation is significant at the 0.001 level (2-tailed), ** Correlation is significant at the 0.01 level (2-tailed), *Correlation is significant at the 0.05 level (2-tailed), ns= not significant, RT= Right, LT=Left, n=number of participants

3.6 Discussion

Adequate muscle strength, power, and endurance enhances participation in daily activities and sports, especially in children with hypermobile joints as they will require more strength to control the extra range of motion. In addition, good joint stability and balance are important in the prevention of injuries during physical activities [8]. Therefore, the aim of this study was to

examine the relationship between joint mobility and different aspects of strength, proprioception, and dynamic balance.

The prevalence of GJH has been reported to be higher among children, females and Africans [55] but there is a lack of consensus on the Beighton score cut off [56,57]. This accounts for the variation seen in the reported prevalence of GJH. According to some authors a Beighton score cut off of ≥4 will result in an overrepresentation of GHJ among children who are predominantly hypermobile [55,58]. This justifies our use of Beighton score cut off of ≥6 in this present study, although it can be considered strict and age specific when compared to previous studies that used Beighton score cut off of ≥4 to identify GJH among children [4,59]. It is interesting that even with our strict Beighton score cut off point, we found a high prevalence of GJH (31%) in our sample compared to outcomes from previous studies among Caucasians [28,60]. This further justifies the plea for the higher Beighton score cut off among children [61]. Although this has not been confirmed in other studies, Sohrbeck-Nøhr 2014 found children with Beighton score of 5 or 6 having greater odds of developing musculoskeletal complaints than those with Beighton score of 4 [62]. It appears that the number of hypermobile joints a child has may be a factor in the onset of musculoskeletal complaints hence the need for higher Beighton score cut off in identifying GJH.

The children in the hypermobile group were significantly younger and with more females which is in line with previous studies [43,55]. Nevertheless, these differences could not explain the results and group differences persisted after correction. Even though GJH is not a disease condition, musculoskeletal complications do arise when individuals with GJH cannot control the extra degrees of motion during physical activities [63]. The effects of these musculoskeletal complications and cost of rehabilitation are far reaching [46]. This implies that understanding the pathway to the onset of musculoskeletal complications in GJH and tailoring it towards prevention and prompt management cannot be overemphasized.

3.6.1 Pain and GJH

In this present study, pain was reported by about 18% of the children but this was unrelated to GJH. In addition, none of the children with GJH had reported pain in three joints or over three months duration nor during performance of the test items. Even though we probed children to discuss their joint pain while completing the questionnaire, it did not seem to hamper them in

the activities. Pain can be a feature of musculoskeletal disorder, but it is not commonly reported in children with GJH [64]. Previous studies have not been able to establish an association between joint hypermobility and pain because children may report pain irrespective of their joint mobility status [2, 65]. It is therefore imperative to look beyond pain in an attempt to find out why some children with GJH are liable to severe musculoskeletal complaints and injuries later in life [2]. Although altered proprioception, lower muscle strength, joint instability, dislocation, and other musculoskeletal impairments have been reported in children and adults with HSD, this trend has not been confirmed in children with GJH [66].

3.6.2 Proprioception and GJH

Proprioception was examined using the wedges test. Although no significant differences were found, children with GJH did not perform worse than children with normal mobility. If anything, they made less mistakes (lower penalty score). This outcome is in line with the study by Ituen et al, and further confirms that joint laxity may not compromise proprioceptive acuity in young children with GJH [53]. Evidence in literature has supported the notion of joint pain because of the relation between poor motor performance and the occurrence of injury [67]. Since joint pain was unrelated with GJH in our study, it was to be expected that the children with GJH had a good functional status.

3.6.3 Functional strength and GJH

In this study, the children with GJH had a significantly better performance in the lower limb items of the FSM except for stair climbing, whereas no differences were found in the upper limb items of the FSM. This difference is important as injuries are expected to happen more often in the loaded positions, thus in lower limbs [68]. An association of leg musculoskeletal symptoms and GJH, has been inconclusive in the literature because the musculoskeletal symptoms among individuals with GJH are variable and temporary [67, 69]. Furthermore, bony structures in the lower limbs provide stability that may reduce the negative effect of hypermobility [28].

The outcome of lower limb functional strength in children with GJH in our study is comparable to the study by Juul-Kristensen et al [70]. In their study, children with GJH had better peak vertical jump displacement than children with normal mobility. Junge et al, also tested jump

distance both in children with GJH and in those with normal mobility and they did not find a difference in their performances [71].

The efficiency of leg movements is based on contributions from both the passive component (ligaments) and active component (muscles) [72]. So, a closer look at muscle activation in individuals with GJH will help us to understand how they are able to move effectively despite the extra degrees of movement at the joint. It is known that muscle activation compensatory strategies can overcome consequences of joint dysfunction [71]. This compensation occurs either by activation of other muscle groups or by co-contraction of muscles, providing the joint stabilization necessary during functional movement and thus preventing injuries [71]. It has been demonstrated in previous studies that neuromuscular strategies in individuals with GJH are different from those with normal mobility [73, 74]. For instance, the ankle is considered to be overactive in children with GJH as studies on electromyography have found activation of ankle muscles to be significantly higher in children with GJH [7], whereas the ankle strategy is only utilized in children with normal mobility during very difficult tasks. In performing the single leg hop test, Junge et al found that children with GJH have an increased activation of the gastrocnemius muscles, which was significantly different from children with normal mobility [71]. Increased co-contraction of muscles is another strategy used by children with GJH to stabilize the joint for better functional outcomes [73]. This was also evident in the study by Greenwood et al, although their study population consisted of children with Benign Joint Hypermobility Syndrome (BJHS) [74]. The co-contraction of rectus femoris and semitendinosus was higher in children with BJHS than in the control group. How effective these strategies are in the long run, given the lower isometric strength level and the increased risk of fatigue is still unknown.

The only lower limb FSM item in which children with GJH did not outclass the children with normal mobility was stairclimbing. Some authors are of the opinion that unlike level walking, stair climbing requires quick stabilization of joints and fast activation of muscles, so it will be more difficult than level walking [72,75]. In fact, stair climbing may therefore provide a prodromal impairment in GJH [12]. The knee joint is very significant in stair climbing, and quadriceps acts as joint stabilizer during that activity. It should be emphasized that stair climbing was still at a high level in GJH. Thus, the lack of significant reduction in scores on stair climbing reflects, that even with lower isometric extensor force, the children successfully

compensated with muscle activation for the laxity of the joints. However, this may change when they grow older.

3.6.4 Isometric strength and GJH

Significantly lower isometric strength (quadriceps, plantar flexors and dorsiflexors) was measured among children with GJH, however, grip strength was not different between groups. Contrary to our findings, Jensen et al., reported no difference in isometric knee strength between children (10 years) and the healthy control in their study [73]. Typically, the presence of pain precedes reduction in physical activities and consequently deconditioning and muscle weakness [76]. However, Scheper et al., argued that muscle weakness in asymptomatic individuals with GJH may not necessarily be only as a consequence of deconditioning secondary to pain and inactivity [69]. They were of the opinion that the elasticity of tendons also influences the amount of force a muscle can generate. In agreement with this, some authors have suggested that structural changes such as reduced tendon stiffness, similar to what is seen in people with connective tissue disorder, may be a contributing factor to muscle weakness in GJH [70,71]. In addition, the possibility of fear avoidance and anxiety because of excess movement and injury exists but this is yet to be explored in children with GJH. The association between GJH and anxiety has been confirmed in adolescents and young adults with GJH

3.6.5 Dynamic balance and GJH

While keeping balance on one leg, children with GJH in our study could not reach as far as those with normal mobility in posterolateral and posteromedial directions, but they performed equally in the anterior direction. Trunk movement and stability of the knee joint is essential during this test. Children with GJH often try to hyperextend their knee to obtain stability. However, to reach further backwards when pushing against the indicator either in medial or lateral posterior direction, the knee of the stance leg needs to flex. Moreover, the trunk needs to lean forward to counterbalance for the back leg in order to keep balance and prevent a fall. Thus medio-lateral stability is challenged in these items in a flexed position of the knee, which might reveal the limits of their compensatory stability.

Even though their study was in an adult population, Hou et al., evaluated balance in individuals with chronic instability using the Star Excursion Balance Test [63]. The authors reported an

initial deficit in posterolateral and posteromedial directions in the group with GJH which improved following a balance training program.

3.6.6 The association between strength and balance

When we consider that joint stability is achieved passively by ligaments and actively by muscle contraction, then the association between strength and balance in GJH is very important. Based on our hypothesis, we expected a strong association between strength and balance, yet our study found a weak (FSM upper extremity) or moderate (FSM lower extremity) correlation with isometric strength when we controlled for age. In contrast, the study by Hou et al. demonstrated a close relationship between balance and strength in hypermobile adults with chronic ankle instability [63]. They found an improvement in balance and a corresponding gain in muscle strength following balance training. The discrepancy between Hou et al. and this study needs exploring. An advantage in the present sample, compared to individuals with chronic ankle instability, is the good level of proprioception. Proprioception is very important in motor control as it facilitates prompt activation of muscle. It is likely that the better lower limb performance on FSM that we found among the children with GJH may be the result of their proprioceptive acuity and lifelong exposure to their joint laxity during daily activities

An unexpected finding was the relative high correlations between reaching distance in the Y-balance and the explosive power items of the FSM. At first sight upper body strength seems less important to keep balance in one leg stance. However, in the Y-balance tasks, reaching the limits of stability depends on moving the upper body as far and steady forwards and backwards to counterbalance the leg movement in the other direction. This might explain the observed association ($r = 0.36$), which is in the same range as the relation with knee ($r=0.34$, $r=0.26$) and ankle muscle strength ($r=0.30$-$r=0.42$) for right and left leg respectively.

3.6.7 Strengths and limitations of study

In this study, a strict Beighton cut-off of ≥ 6 as recommended in literature was used, which makes our study population with GJH highly mobile. Even though we had a large sample size, some of the children did not take part in all tests. However, we are confident that the remaining number of participants was high enough to support the claims made.

Our study has also provided data on functional tasks like stair climbing or lifting a heavy box in children with GJH, which is scarce in literature, making comparisons with other studies difficult. Clinically, tests of dynamic balance and functional strength should be included in assessment protocol because they are more related to activities of daily living. Also our study provides evidence of stair climbing as a prodromal impairments for children with GJH. In addition the items of the FSM are more cost effective and easily assessable than the HHD. However, we believe that the assessment of dynamic balance and functional strength is relevant to our activities of daily living. The measurement of isometric strength was done with HHD, which makes it objective, but the method has its limitations.

3.7 Conclusion

Although functional strength was significantly higher in the lower limbs of children with GJH, this study showed impaired isometric strength in their lower extremity. Our results indicate that hypermobility did not compromise proprioception and functional motor performance because the children may have established compensatory strategies to cope with their extra range of motion. The value of isometric force may be overestimated, since the present results clearly demonstrate that force, measured as functional strength, is not decreased in this population. However, the long-term effect of these compensatory strategies on the musculoskeletal system still needs to be discovered.

3.8 References

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Chapter 4: Proprioception and its Relationship with Range of Motion in Hypermobile and Normal Mobile Children

4.1. Preface

During functional activities, changes in body positions and joint movements are happening simultaneously. One's ability to perceive body position and joint movement in space is referred to as proprioception. Proprioceptive stimuli arise from sensory information received from mechanoreceptors, found in joints, muscles, tendons and the skin [94]. Precision in awareness of body position and joint movement is very important for preventing injuries.

Impaired proprioception has been associated with pathology in children with Generalized Joint Hypermobility (GJH) who have developed musculoskeletal symptoms, however, it is not clear if it is solely a result of the destruction of mechanoreceptors at the joints, as mechanoreceptors are also present in the muscles and skin [95]. It is assumed that hypermobility may cause instability which, over time, makes the joint susceptible to micro and macro trauma.

An earlier study by Ituen et al. (2020) queried the association between joint laxity and poor proprioception because children with GJH were not different from children with normal mobility in their ability to discriminate heel height [53]. They argued that the outcome could have been because the children were tested in the standing position.

In the study presented in this chapter we tested proprioception using wedges (an ecologically valid instrument) in both weight-bearing and non-bearing positions. We also tested proprioception in the upper limbs, using the joint repositioning task method.

The similarity in proprioception between children with and without GJH in this present study confirms that children with GJH may not be inherently predisposed to injuries that lead to the destruction of mechanoreceptors and subsequent impairment of proprioception. Based on the outcome of this study, there is a need to re-evaluate our understanding of injury risk and hypermobility as well as the treatment protocols created for children with GJH. These protocols generally focus on training proprioception, which appears to be unnecessary in this group. In addition, the study's outcome provides direction for future studies on adolescents with GJH.

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RESEARCH ARTICLE

Proprioception and its relationship with range of motion in hypermobile and normal mobile children

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Abstract

To investigate differences in proprioception using four proprioceptive tests in children with and without hypermobility. Additionally, it was tested if the results on one proprioceptive test predict the results on the other tests. Of the children (8-11years), 100 were classified as normal mobile (Beighton score 0–4) and 50 as hypermobile (Beighton score 5–9). To test proprioception, in the upper extremity the unilateral and bilateral joint position reproduction tasks were used and for the lower extremity the loaded and unloaded wedges task. No differences were found in any of the proprioception tests between the two groups. Estimating the height of the wedges was easier in the loaded position (mean penalty in standing and sitting position, 4.78 and 6.19, respectively). Recalling the elbow position in the same arm resulted in smaller errors compared to tasks reproducing the position with the contralateral arm. Of the four angles used (110°, 90°, 70°, 50°), the position recall in the 90° angle had the smallest position error (1.8°). Correlations between the proprioception tests were weak (Loaded and Unloaded (r 0. 28); Uni and Bilateral (r 0.39), Upper and Lower extremity not significant). No indication of poorer proprioception was found in children with hypermobile joints compared to their normal mobile peers. Loading gives extra information that leads to fewer errors in the wedges task performed while standing, but this effect is independent of joint mobility. Proprioception test outcomes are dependent on the test used; upper extremity results do not predict lower extremity outcomes or vice versa.

Keywords Hypermobility · Children · Proprioception · Joint loading

4.2 Introduction

If proprioception depends on joint mobility one would predict worse proprioception in hypermobile children. Joint Hypermobility (JH) is the ability of a joint to move beyond the normal range of motion as a result of laxity of ligaments (Castori & Hakim, 2017). When it occurs in multiple joints it is referred to as Generalized Joint Hypermobility (GJH) (Przymuszala et al., 2018). Its prevalence in the general population usually is influenced by age, gender and race (Kwon et al., 2013). The Beighton scoring system has been commonly used to identify children with GJH (Malek et al., 2021). The prevalence of GJH has varied between 8.8% and 64.6% in literature partly because of the lack of consensus on the Beighton score cut off (Ituen et al., 2023). Previous studies have used Beighton score cut-offs ranging from ≥3 to ≥6 (Reuter & Fichthorn, 2019; Kurniawati et al., 2021).

GJH is a physical trait that is viewed as the end of the normal spectrum of joint mobility and it is predominately asymptomatic; it is perceived to be beneficial in motor activities that require flexibility (Tofts et al., 2009; Van Meulenbroek et al., 2020). In contrast, GJH may also represent a polygenic group of a mild end of the spectrum of the Heritable Disorders of Connective Tissues (HDCT) because of its association with musculoskeletal symptoms such as pain, sprains, impaired proprioception, reduced muscle strength, and poor motor coordination (Engelbert et al., 2017; Maarj et al., 2023). This is referred to as Hypermobility Spectrum Disorder (HSD). However, not all children with GJH become symptomatic and the evidence on the role joint laxity plays in the pathology of musculoskeletal symptoms in literature has not been conclusive (Simmonds & Keer, 2007).

Proprioception is the awareness of the body in space and it is essential in motor control and coordination (Virginia, 2017). Children with GJH have been described as clumsy with associated impaired proprioception (Akkaya et al., 2023). However, gap persists in the literature about possible proprioception deficits in children with hypermobility without musculoskeletal complaints because previous authors have tested proprioception using different instruments and test positions (Smith et al., 2013). Hence there is a need to retest the potential proprioceptive deficit in these children.

In an earlier study, we used wedges to test proprioception in the lower extremity in children with GJH in a weight-bearing position and no difference was detected compared to controls

(Ituen et al., 2020). In a more recent study, we modified the heights of the wedges making the test more difficult, yet it did not reveal a difference between children with and without GJH (Anieto et al., 2023). It is yet to be tested if the outcomes will be different when the wedge test is performed in unloaded positions. Given the additional input from load receptors in the loaded condition one expects better performance in the loaded condition as compared to the unloaded one. Furthermore, it can be argued that the absence of difference between mobility groups in our previous studies could be due to the choice of the lower extremity while most studies used upper extremity tasks. The most frequently used upper extremity tests are the unilateral and bilateral elbow position matching tasks Therefore, we administered both upper and lower extremity tasks in children with and without hypermobility.

Peculiar to joint hypermobility is the abnormal joint biomechanics arising from the laxity of the joint connective tissues (Pacey et al., 2010). It is assumed that the demand to maintain joint stability may put some strain on the connective tissues causing repetitive micro and macro trauma over time (Tinkle, 2020). The long-term effect may be a gradual destruction of mechanoreceptors at the joints and deficits in their function (Anieto et al., 2023). Mechanoreceptors are located in the joint capsular tissues, ligaments, tendons, muscle, and skin tissues and perform the function of passing sensory stimuli to the central nervous system for processing, resulting in appropriate motor responses (Ageberg et al., 2007). Appropriate functioning of these mechanoreceptors is important for the role of proprioception in motor performance and physical activities (Han et al., 2016).

The aims of the present study were firstly to compare the outcomes on proprioception in a comprehensive set of tests (four different target angles in the upper limbs and wedges in loaded and unloaded positions in lower limbs between children with and without GJH). Secondly, we investigated whether the loaded wedges task was superior to the unloaded task and if the results in one proprioceptive test predicted the results in the other tests.

4.3 Materials and methods

4.3.1 Procedure

The study used a cross-sectional descriptive design and was conducted following the Declaration of Helsinki. The study's ethical approval was obtained both from the human

research ethics committee of the University of Cape Town (UCT HREC: 096/2015, HREC REF: 306/2021) and the University of Uyo Teaching Hospital REF: UUTH/AD/S/96/VOL/ XXI/524. The secretary of the Local Government education Uyo, along with the head teachers and class teachers at the selected schools, all granted permission to carry out the test on the children. Schools were selected through the convenience sampling method. Our study exclusion criteria were: children with cognitive and gross motor impairment, as reported by their parents, because these limitations would affect their ability to understand the testing instructions or their performance of the activities. However, none of the children had to be excluded using the above criteria. The study sample size was calculated through a power analysis that showed that a total sample size of 134 was needed for a medium effect size (d= 0.6), at a power of 90%, while alpha was set at 0.05 with an allocation ratio of 2. The G-power analysis software version 3.1.9.2 was used for the sample size calculation (Faul et al. 2007). Written informed consent was obtained from the parents or legal guardians of the children, and assent was given by the children before their enrolment. The children were tested by seven trained researchers in their school. The children were given breaks between tests or at their request.

4.3.2 Demographic measures

Data were collected on participants' age (years), sex, height (centimeters), and weight (kilograms). Height and weight were measured using measuring tape and a weighing scale (on bare feet; measured to the closest one cm and 100 g, respectively). The body mass index (BMI) calculation was performed using a metric formula, weight (in kilograms) divided by height (in meters squared).

4.3.3 Beighton Score

The nine-point Beighton score, with goniometry, was used to assess joint mobility (Ituen et al., 2023). The test consists of bilateral assessment of the 5^{th} metacarpophalangeal (MCP), elbow, knee joints, thumb movement and one active forward trunk flexion task. A score of 0-9 was used to divide joint mobility into two categories, normal mobility (0-4) and hypermobility (5-9) (Nikolajsen et al., 2013). The Beighton test has been validated among children (Smits-Engelsman et al., 2011).

4.3.4 Experimental protocol

For the upper extremity proprioception test, the joint position reproduction (JPR) using a goniometer was used as the method of measuring position sense by repositioning. We tested elbow JPR unilaterally and bilaterally, randomizing the order of tasks and angles in both experiments. The tests were carried out with the child seated, arms by the side and blindfolded. Starting with either the preferred (four trials) or the non-preferred side (four trials), the order of test angles was random. A first tester passively moved the arm in the coronal plane (arm to the side with the shoulder at about 90°), then moved the elbow joint to the target angle (50^0,70^0,90^0,110^0) and the child was asked to concentrate on the angle while the tester maintaining this position for 10s. Then the tester dropped the hand by the side of the child. The child was then asked to reposition the elbow without delay to the detected angle, and the measurement was taken with a goniometer by the second tester. The convention was used that 0° represented a fully extended arm with the forearm horizontal, and the 90° position was a flexed arm with the forearm in the vertical position. The difference between the target angle and the child's test result was determined as the error score. Half of the children started the trials with the dominant hand and the other half with the non-dominant hand. Three measurements were made for all target angles, and the arithmetic mean of the differences was calculated.

4.3.4.1 Unilateral (ipsilateral) Joint Position Reproduction task

The tester presented four target angles to the right and left arm, thus subjects performed 8 ipsilateral matching trials (with 3 repetitions). The right or the left elbow was passively moved from the starting position to one of the four target angles earlier described. After the tester returned the arm to the baseline position, subjects then repositioned the same arm to the target angle and the tester measured with the goniometer.

4.3.4.2 Bilateral (contralateral) Joint Position Reproduction task.

The tester passively moved the elbow to one of the same four angles as mentioned in the experimental protocol for the unilateral task. The subject was then asked to position the contralateral arm in the target angle. The other tester measured the angle of the contralateral

arm with the goniometer. The tester presented four target angles thus subjects performed 8 contralateral matching trials (with 3 repetitions).

4.3.5 Wedges Test

Using different wedges under the feet the ankle angle can be varied, and the perceived height can be measured. This can be done in weight-bearing (loaded) position (ituen 2020) but here it is also assessed in non-weight-bearing conditions.

4.3.5.1 Loaded task

We tested proprioception (detection of heel-height difference) using the wedges of various heights that produce different angles equal to contact surface of 1.5°, 3°, .4.5°, 6°, 9° and 12°. The 1.5°, 4.5° wedges were added (similar to Anieto et al. 2023) to have more combinations with only 1.5° difference (1.5° versus 3°, 3° versus 4.5°, 4.5° versus 6°). Participants stood behind a table and were not blindfolded during the testing but were instructed not to look at their feet under the table while the test was conducted. While standing on the wedges, (without support from the table) they raised the arm of the side with the higher ankle, for example, the right arm for the right ankle. Both arms were raised when no difference in ankle height was detected. The subject had 5s to respond. A penalty score was awarded for every incorrect response, and the size of the penalty was determined by differences in the height of the wedges. The higher the wedge height difference, the higher the penalty score. The individual penalty scores of the 21 test trials were summed up to get a total penalty; a high penalty score indicates poor proprioception.

4.3.5.2 Unloaded task

The unloaded version of the test was carried out with the participants seated on a chair with the back rested against a wall to minimize the weight on the leg during the test and their knees were positioned at 90^0. With eyes closed, the wedges were placed under the feet of the participants, and they were asked to raise the hand on the side of the ankle with the higher ankle. Both arms were raised when no difference in ankle height was detected. The subject had 5s to respond.

4.4 Statistical analysis

All variables were examined to determine whether distributions were normal or skewed. No outliers were present in the data, except for 2 data points in the loaded wedges task, which were removed. T-tests were used to test for differences in demographic variables between the two groups and Chi^2 to test the gender distribution over groups.

A GLM Repeated Measures was used to examine the effect of JPR tasks (Uni and Bilateral) hand (Preferred and Non-preferred), angle (110°, 90°, 70°, 50°) as within-subject factors and group (Hypermobile, Normal mobile) as between-subject factor and to test for possible interactions. A second GLM Repeated Measures was used to examine the effect of loading in the wedges task (Loaded and Unloaded) as within-subject factors and group (Hypermobile, Normal mobile) as between-subject factor. Post hoc tests with Bonferroni correction were used if interactions were found. Pearson's correlations were conducted to assess the relationships among the proprioception test performances. The significance level was set at $p < 0.05$. All statistical analyses were conducted using the statistical package for the social sciences software (SPSS, version 29.0, SPSS Inc., Chicago, IL, USA).

4.5 Results

4.5.1 Demographic data

A total of 150 children were included in the study, eighty-five (57.3 %) of the children were girls and 64 (42.3 %) were boys. Demographic data such as age, height, body weight, and BMI of children with and without GJH were not different ($p > 0.05$) (Table 4-1). Participants were classified as GJH with a Beighton score ≥5/9.

Table 4-1: Demographic characteristics of the participants

Demography	Children with GJH n=50 mean ±SD	Children without GJH n=100 mean ±SD	Total group n=150 mean ±SD	p-value
Age (years)	9.26 ±0.89	9.46 ±0.83	9.39 ±0.86	0.674
Weight (kg)	28.32 ±6.62	27.14 ±5.78	27.53 ±6.07	0.214
Height (cm)	134.58 ±8.38	134.10 ±8.46	134.26 ±8.41	0.473

BMI (kg/m^2)	15.50 ±2.60	15.02 ±2.45	15.18 ±2.50	0.136

GJH=Generalized Joint Hypermobility, kg=kilogram, BMI= Body Mass Index, cm=centimeter, m=meter, n=number of participants

4.5.2 Joint Position Reproduction Tasks.

An overview of means and confidence intervals are given in Table 4-2.

Table 4-2: Means (SE) of the errors (in degrees) for the two mobility groups of all the conditions of the joint position reproduction tasks.

	Mean	Standard error	95% Confidence Interval	
			Lower Bound	Upper Bound
Mobility group				
GJH				
Without GJH				
Body side				
Preferred	5.56	0.27	5.04	6.09
Non-preferred	5.29	0.23	4.83	5.75
Target angle				
110^0	4.30	0.24	3.83	4.76
90^0	1.84	0.16	1.54	2.15
70^0	7.34	0.35	6.66	8.03
50°	8.22	0.53	7.17	9.27
Task				
Unilateral	4.34	0.21	3.92	4.76
Bilateral	6.51	0.29	5.93	7.09

GJH= Generalized Joint Hypermobility.

4.5.3 Main effect of group: Hypermobile versus Normal mobile

No group differences were found in the position errors on any of the tasks between groups ($F_{1,147} = 0.00$, p 0.992). Notably, no interactions with Task, Angle or Arm emerged with group. This indicates that children with and without hypermobility responded similarly to the task conditions.

4.5.4 Main effect of side: Preferred /Non-Preferred

No main effect of arm was found (F(1,147) 1.090, p= 0.298). Although the mean error for the non-preferred arm seems lower (better performance) this was far from being significant (5.56° and *5.29* ° (see figure 4-1a), respectively for the Preferred and Non-Preferred arm (p=0.289).

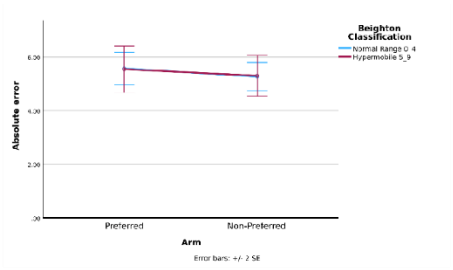

Fig. 1a

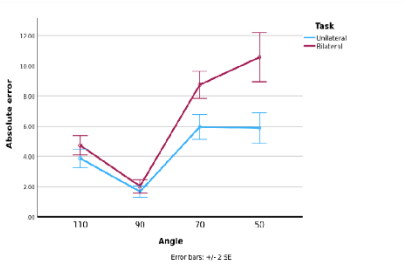

Fig 1b

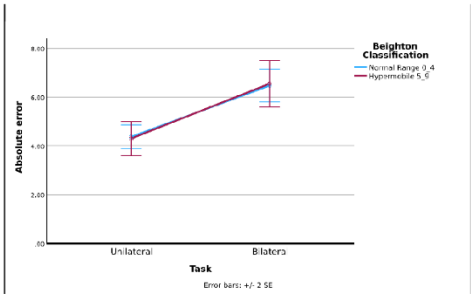

Fig 1c

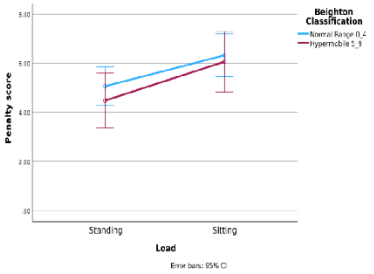

Fig. 1d

Figure 4-1: Means (SE) of the errors (in degrees) for the two mobility groups of all the conditions of the Joint Position Reproduction tasks.

4.5.5 Main effect of target angle: 110^0, 90^0, 70^0, 50°.

A large main effect of the angle occurred (F(3,145) 106.75, p < 0.001). In the 90^0 angle, the position recall had the smallest position error (1.8°). The more flexed angles in the elbow were clearly harder to match 7.3° and 8.2° errors for the 70^0 and 50° angles, respectively as shown

in Figure 4-1b. Post hoc showed significant differences between all angles except between 50 and 70^0.

4.5.6 Main effect of task: *Unilateral versus bilateral* Joint Position Reproduction tasks (UNI/BI)

The error was different in the recall of the position in the same arm (UNI) compared to putting the contralateral arm at the same angle as the reference arm (BI) (F(1,147) 57.36, p <0.001). Children were better at reproducing the position in the unilateral (error 4.3°) than the bilateral matching task (error 6.5°), as shown by the smaller absolute error (Figure 4-1c). Here, the only interaction in the analysis emerged: task (Uni/BI) by angle (F(3,145) 10.76, p =0.001). Post hoc showed no effect of task (Uni/BI) in the 90-degree angle. It also showed that the negative effect in the bilateral task is larger in the more difficult angles (70^0 and 50^0) (Figure 4-1b). In the bilateral task, all angles were significantly different, while in the Unilateral 50 and 70 degrees the errors were not different from each other.

4.5.7 Wedges

No differences between hypermobile and normal mobile children on penalty score were found (F (1,148) 0.15, p=0.70). The height discrimination results of children with and without GJH were similar ($p > 0.05$). Importantly, an effect of loading was shown (F (1,148) 11.89; p<0.001; η^2_p 0.074; Figure 4-1d), indicating that discriminating between the height of the wedges was easier in standing than sitting (mean penalty in standing and sitting position, 4.78 and 6.19, respectively).

4.5.8 Associations between the different proprioception tests

The correlation between the penalty score Loaded and Unloaded was (r =0. 28, p<0.001) between Uni and Bilateral position errors (r 0.39, p<0.001). Because it was expected that the mobility of the elbow (range of motion) might have an impact on the two position-matching tasks, the correlation between these measurements was also determined. Similarly, the correlation between the knee and ankle mobility and the Wedges outcomes were also examined. Elbow range of motion was not significantly related to the position sense tasks.

Knee and ankle range of motion showed no significant relation with loaded or non-loaded wedges results. The correlations between upper and lower extremity proprioception items were not significant.

4.6 Discussion

The first aim of the present study was to examine whether the earlier finding of an absence of a proprioceptive deficit in GJH remained valid when broader testing was applied, that is wedges test in loaded and unloaded positions in lower limbs (Ituen et al., 2020, Anieto et al., 2023), along with elbow joint position tests. The results show that none of the added tests revealed a significant difference between GJH and controls, thereby reinforcing the idea that proprioception (as tested with a broad range of tests) is not affected in asymptomatic GJH. These findings are in line with those of Pacey et al 2014. They studied children with more severe disease (symptomatic joint hypermobility), yet found no evidence for altered proprioception, similar to our findings on asymptomatic GJH.

These are important results since previous studies had suggested that a proprioceptive deficit existed and justified a program of proprioceptive training (Fatoye et al., 2009). However, the latter study was conducted by testing knee position sense on hypermobile children with painful knees. Another study based on 20 hypermobile children, concluded that there was a proprioceptive deficit but they only used ankle reposition at a single flexion (15^0) and extension angle (25^0) (Akkaya et al., 2023). Hence overall the evidence for a proprioceptive deficit is weak.

From an absence of proprioceptive deficit one would predict that physical activity is relatively normal in this hypermobile group. Indeed, no difference in daily level and duration of physical activity was observed in a group of 8-year-old school children with generalized joint hypermobility (Juul-Kristensen, et al, 2009). A possible factor is that there is an element of compensation. For example, there is evidence that GJH children use a different muscle co-activation strategy to stabilize joints (Jensen 2013). In addition, physical condition may be a crude parameter and finer testing may reveal deficits. For example, Anieto et al. (2023) found an association between joint mobility and motor performance, as measured with the PERF-FIT).

Is the wedge test a valid instrument?

A possible first objection to the previous use of the wedge test was that it was performed under loaded conditions, allowing a major contribution of load receptor input, in contrast to most joint position tests. It was indeed found that the loaded test yielded better results (smaller errors) than the unloaded version. However, the unloaded version did not reveal a performance difference between the two groups investigated, thereby eliminating the presence or absence of load as a factor in the absence of a proprioceptive deficit. Several elements could contribute to the superiority of the loaded version, including the addition of load receptor input (Gooey et al., 2000) and a role of central command (Proske & Gandevia, 2009). Inversely, the inferiority of the unloaded version could be related to the leg muscles being relaxed, leading to a greater likelihood of a thixotropic effect (Proske et al., 1993). Such weight-bearing superiority was also observed in knee joint matching tests as described by Stillman and McMeeken (2001), although in their case the situation was more complex as the subjects were able to use cues during movement of the knee between positions (Stillman & McMeeken, 2001). In addition, these authors found no clinically significant correlation between the weight-bearing and non-weight-bearing results, confirming our present results.

Another objection, which could be used against our previous results, was that they all involved the lower limb while joint position tests are more commonly performed with the arms. The presently added arm tests again failed to show differences between the two groups. Furthermore, the correlations between arm and leg tests were not significant. This is not surprising as a recent review on the topic concluded that results with respect to one body part may not be generalized to others (Horvath et al., 2023). The current tests were performed on each arm separately and it was found that the mean error for the non-preferred arm was slightly lower than for the preferred arm. Although not significant, this result is in line with current literature (Goble, Lewis, & Brown 2006). We also compared unilateral (one-arm repositioning) and bilateral (two-arm matching) elbow joint position tests and found bilateral tests to yield worse results than unilateral ones. This could have been expected since many more computations are required in bilateral testing. For future work it would be of interest to have a bilateral condition without repositioning but with different angles on both sides to make subjects decide which side was most extended (in analogy with the wedges test).

For the unilateral matching, it was of special interest that the error depended on arm position (angle). For both the unilateral and the bilateral testing the optimum was reached for elbow angles around 90 degrees (hence forearm in a vertical position). This is similar to the findings of Roach et al (2023), who found that the smallest repositioning errors were seen at an elbow angle near 90 degrees (Roach et al., 2023). What is so special about holding the lower arm in an upright vertical position? Stretch of muscle spindles, skin or joint receptors is higher at other angles. Torque sensation is likely to be at a minimum at 90 degrees and should not be overlooked as an accessory source of information in limb positioning (Worringham & Stelmach, 1985). In addition, there may be a perceptual component. In the visual system, it is known that vertical and horizontal line orientations are best for orientation discrimination ("oblique effect") (Orban et al., 1984). This bias persist even when the head is tilted, thereby suggesting that it is mostly an allocentric effect (Mikellidou et al., 2015). More generally, a crucial factor is the "subjective vertical", the perception of verticality (Dakin and Rosenberg, 2018), When subjects are asked to judge elbow position with respect to the vertical they are better than when focusing on joint angle (Soechting, 1982). The latter author concluded that position sense at the elbow joint includes a sense of the orientation of the forearm with respect to a spatial frame of reference, while the elbow joint angle is only imperfectly sensed. The question arises which afferents contribute to the normal responses in the hypermobile population. Could joint receptors be involved? If laxity of ligaments is a problem, then it would be expected that torque at the joint would be reduced and this would lead to a fall in joint receptor input, especially at the limits of the movement range at the joint. Therefore, it is more likely that muscle spindles are the main sensors involved. This is in line with the general notion that spindle afferents (especially the Ia afferents) are the principal contributors to position sense (Goodwin et al, 1972).

Returning to our main result and the evidence supporting the notion of an absence of a proprioceptive deficit in asymptomatic GHS, the question remains whether some subtle proprioceptive deficiencies exist, not captured by our tests. According to Héroux et al., 2022, proprioceptive tests can be classified as either a low-level or a high-level task. Repositioning is seen as low-level by some (Héroux et al., 2022) because a single frame of reference is used but others consider this to be a high-level task since higher functions (such as memory) are involved (Roach et al., 2023). Nevertheless, it is only one form of high-level testing, while

others are available, for example tests in which subjects are required to indicate where their unseen hand is.

Motion sense would also be of interest to measure since it potentially involves a different set of afferent input (Krewer et al., 2016). Joint position sense and movement detection were shown to correlate poorly and therefore both are worth examining to obtain a more complete picture of proprioception (Grob et al., 2002). However, so far no evidence was found for deficiencies in more dynamic conditions as we found no differences between a GJH group and a control group on the Y-balance performance, a test that requires a reach movement with the free foot while standing on one leg (Ituen et al., 2024).

In hypermobile people with Ehlers-Danlos syndrome (EDS), joint angle matching does not reveal any difference with controls (similar to the present study on generalized hypermobility). In contrast, a hand position test showed the hypermobile EDS subjects to be less accurate than controls (Clayton et al., 2021). This emphasizes the complexity of the notion of proprioception and points to potential follow-up studies, using hand position testing, on GJH children.

4.7 Conclusion

The current data show that there is no evidence for a proprioceptive deficit in children with generalized hypermobility as tested with a broad set of proprioceptive tests.

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Chapter 5: Impact of Generalized Joint Hypermobility on Quality of Life and Physical activity in School-Aged Children: A Longitudinal Study

5.1. Preface

The effect of the musculoskeletal symptoms in Generalized Joint Hypermobility (GJH) is usually regarded as benign because they are usually not life-threatening [96]. Notwithstanding, the altered biomechanical condition in GJH is believed to increase the risk of injury, and even overloading at the surrounding tissues. The most common feature of HSD is pain, which may be followed by functional difficulties, activity limitation(s), poor physical fitness and poor Quality of Life (QoL) [97,98]. It is not known if there is a long-term effect of repetitive trauma in individuals with GJH that can ultimately affect their quality of life.

There are psychosocial implications of GJH, because the fear of injury can lead to avoidance of physical activities, thereby reducing activity participation, which can lead to isolation and depression [95]. In the school setting, poor handwriting is a functional difficulty associated with joint laxity. Whether this will cause low self-esteem in children with GJH is a psychosocial problem yet to be explored [99].

Longitudinal data, particularly on GJH and QoL is scarce in literature, so the aim of the study presented in this chapter was to investigate the impact of joint laxity on physical activity, physical fitness and QoL a period of two years, taking three measurements.

Firstly, ethical approval was obtained from the Human Research Ethics Committees of the University of Cape Town (HREC REF: 306/2021) and the University of Uyo Teaching Hospital (REF: UUTH/AD/S/96/VOL/XXI/524). Permissions were obtained from each school head and class teachers. In the first year of recruitment, only children aged 6-9 were included in the study. We excluded children with any form of motor or learning disabilities (as reported by parents) because of their negative impact on motor performance. The information and

consent form were sent to the parents of the selected children. The information letter contained the contact information of the PhD candidate and the supervisory team for the parents who would require further clarifications. Only the children with positive consent from their parents participated in the study. In addition, the children gave assent before the tests and questionnaires were administered. The children were at liberty to withdraw from the study without consequence.

This present study compared detailed level of physical activity between children with GJH, and those with normal mobility, using the physical activity questionnaire [100]. In addition, QoL was assessed, using the Pediatric Quality of Life Inventory (PedsQL) 4.0, a health-related inventory, comprising physical, social, and emotional health, and school domains [101]. The participants' physical fitness level were tested using the 20-minute Shuttle Run test.

Physical activities are bodily movement that are produced by the skeletal muscles and results in energy expenditure while physical education is part of the school curriculum that offers students the opportunity to engage in various physical activities. We recommend that children engage in physical activities such as walking, cycling, dancing, skipping, jogging, running and ball games during their physical education periods [102].

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Impact of generalized joint hypermobility on quality of life and physical activity in school-aged children: a longitudinal study

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Abstract

Background Generalized Joint Hypermobility (GJH) offers flexibility that could enhance motor activities. However, if it leads to injury and pain, it increases functional difficulties and activity limitations. The far-reaching consequences of activity limitations and restricted participation include poor physical fitness and diminished quality of life. This study investigated whether variations in joint mobility are associated with physical activity levels, physical fitness, and overall quality of life (QoL) among children and whether these factors change over a 2-year period.

Method One hundred and sixty-five school-aged children were recruited at the beginning of a two-year longitudinal study. One hundred and eleven children were measured three times at one-year intervals. Joint mobility was classified as normal mobile, mobile, or hypermobile. The children were administered the FACES pain scale, the child activity limitation interview, a physical activity questionnaire, and the pediatric quality of life inventory questionnaire. Additionally, the 20-meter shuttle run was used to estimate aerobic fitness.

Results In this study, pain was unrelated to joint mobility. The activity limitations of our study population were not different at baseline or at the end of the study, irrespective of joint mobility. Children with GJH had significantly lower physical activity levels at the end of the study. Overall, QoL increased over time, and aerobic capacity decreased. However, changes in children with GJH were not significantly different from those in children with normal mobility in this respect.

Conclusion Children with GJH were moderately active, however significantly less than children with normal mobility. Joint mobility had no significant effect on activity limitations, physical fitness or QoL.

Significance

What is known?

• Increased joint mobility reduces physical activity levels.

What is new?

• Children with GJH were not more limited in their activities than those with normal mobility, as measured by the activity limitation interview.

• Children with GJH do not have a greater risk of developing pain-related activity limitations.

5.2 Introduction

Generalized Joint Hypermobility (GJH) arises from ligament laxity found in multiple joints and is commonly assessed via the Beighton scoring system [1]. The prevalence of GJH is notably high among children, and it is particularly advantageous in physical activities that require flexibility [2]. Nevertheless, the laxity of ligaments makes the joint biomechanics atypical, which makes the joints more susceptible to instability and repetitive macro- or microtrauma [3,4]. For these reasons, children with GJH have a greater risk of sustaining injuries and experiencing musculoskeletal pain, which can limit their participation in physical activity (PA), reinforcing a sedentary lifestyle [5]. In addition to the ability to acquire motor skills [6], participation in PA is a crucial indicator of positive health outcomes that promote physical fitness, enhance social interactions, and reduce stress, anxiety and depression [7,8]. However, when a child with GJH begins to experience functional difficulties as a result of pain, keeping up with academics and activities of daily living (ADL) becomes difficult [9]. The consequences over time include a sedentary lifestyle, lower physical fitness, stigmatization, isolation and poor quality of life (QoL) [10,11]. The assessment of health-related QoL comprises elements of the physical, emotional, social, and school domains, and it is particularly relevant in children with GJH because of its association with physical and psychosocial impairments [11].

Although joint laxity has been attributed primarily to the onset of symptoms in GJH, evidence of this causal relationship is still lacking [12]. As a result, it is still underdiagnosed, and the mild symptoms of GJH can turn into a debilitating condition due to delays in management [13]. In addition, there is still conflicting evidence on GJH and PA in the literature [14,15]. Some authors have argued that the lack of longitudinal data on GJH may cause a gap in understanding of the relationship between GJH and the onset of musculoskeletal symptoms [16,17]. There are opinions in the literature that GJH may not be entirely harmless, which is why it is included in the differential diagnostic criteria of hypermobility spectrum disorder (HSD) [18]. In previous studies, children with HSD have demonstrated reduced PA levels, poor physical fitness, and QoL [10,19], reinforcing the need to investigate the impact of GJH on PA, physical fitness, and QoL over time.

Thus, the purpose of this study was to determine the level of pain, activity limitations, physical activity, quality of life, and aerobic fitness in a group of school-aged individuals with different

levels of joint mobility. Data collected at the same point in time cannot contribute useful information toward causal inferences. To evaluate the natural history for causal inference, we tested whether the level of pain, activity limitation, physical activity, quality of life, and aerobic fitness changed among three measurements taken one year apart. We also compared whether the pattern of change differed between groups presenting with various levels of joint mobility. Based on assumption in literature, we hypothesized that overtime, children with GJH will report poorer quality of life [20], reduced physical activity levels [21], greater functional difficulties as a consequence of increased pain [22] than children with normal mobility.

Based on the cross-sectional literature, decreasing levels of QoL, fitness [2], and physical activity are expected and more limitations over time in children with hypermobility. However, a prospective study is needed to examine these relationships.

5.3 Materials and methods

5.3.1 Study participants

A prospective cohort study design was employed in this research. Nine schools in the urban area of Uyo local government area, Akwa Ibom state Nigeria were conveniently selected due to access to the pupils. The recruitment period was from 20th September 2021- 31st October 2021. The children were measured thrice at one year interval. The tests were carried out in the school compounds during the children's physical education and break periods. Children aged 6-9 years were eligible to participate at the start of the data collection. The numbers lost to follow-up due to relocation or changes in schools are presented in Figure 1. The exclusion criteria at the start of the study included the following: i) the presence of an acute musculoskeletal injury on the day of or within 3 days before the assessment ii) diagnosis of developmental disabilities such as cerebral palsy or Down syndrome known to impact motor coordination, as reported by a parent or teacher. The sample size was calculated through a power analysis, which revealed that a total sample size of 54 was needed for a medium effect size (f= 0.25) for the main outcome (pain-related activity limitations), with a power of 95% and an alpha of 0.05. Given the longitudinal design, we over recruited to ameliorate the effects of attrition during the study. G-power analysis software version 3.1 was used for the sample size calculation [23].

Procedure

First, joint mobility, height, and weight were measured. The body mass index (BMI) was calculated via the metric formula weight (in kilograms) divided by height (in meters squared). Next, the shuttle run test and questionnaires were administered to the children by trained researchers in their schools. These steps were repeated in the subsequent year

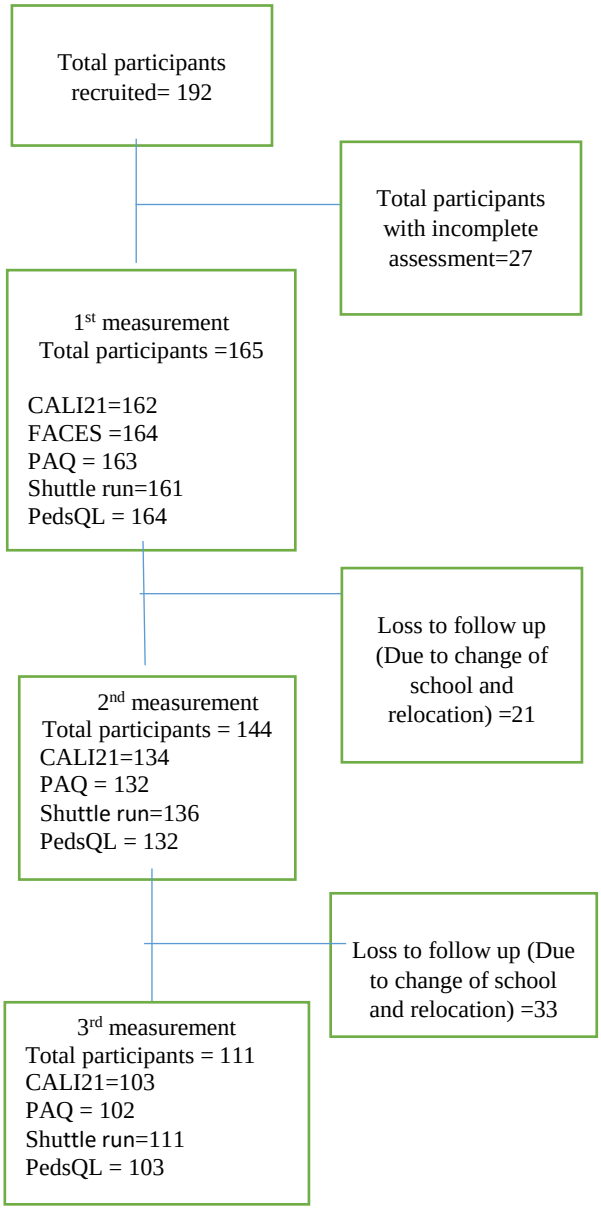

Figure 5-1: Flowchart of recruitment of study participants, N=Number of participants, CALI21 = Child Activity Limitation Interview-questionnaire version 21 X, PAQ-C= Physical Activity Questionnaire for Children. PedsQL= pediatric quality of life questionnaire

5.3.2 Beighton scoring system

The Beighton scoring system has been validated among children and was used to classify GJH in our study [24]. The participants' total possible score on the Beighton test ranged from 0--9, and we classified joint mobility into three categories as follows: 0--4 =normal mobile, 5--6=mobile, and 7--9=hypermobile [25].

5.3.3 The Faces Pain Scale

The Faces Pain Scale (FPS) is an easy-to-use self-report scale that uses facial expressions to assess pain intensity [26]. The FPS is a valid instrument, is comparable to other numeric and observational pain scales [27]. The Faces Pain Scale was selected for this study to establish the prevalence of pain among the participants and whether pain increased over time.

5.3.4 Child Activity Limitation Interview

The Child Activity Limitation Interview-questionnaire version 21 (CALI-21) is a self–reported assessment of pain-related activity limitations in children and adolescents [28]. The CALI-21 is a valid and reliable instrument that has an excellent ICC of 0.96 for child reports and 0.95 for parent reports [28]. The score is calculated by summing the ratings of all 21 items (possible range: 0–84). A higher CALI-21 score indicates greater impairments or pain-related activity limitations [29].

5.3.5 The Physical Activity Questionnaire for Children

The Physical Activity Questionnaire for Children (PAQ-C) is a valid, self-administered, 7-day recall questionnaire that measures the PA level of a child during the school year [30,31]. The children completed the questionnaire, and research assistants provided further explanations when needed. The PAQ-C consists of 10 questions. Question one is a checklist of spare time activities such as walking, dancing, football, swimming, etc. [32]. Questions 2--8 assessed PA during a physical education class, recess, lunch, evening, after school, and on weekends. Question nine asked about their daily (Monday–Sunday) PA levels. The 10^{th} question aimed to determine whether the child missed school the previous week with the reason indicated. Like in the study by Voss et al., we removed 10 activities from the spare activity checklist that did not apply to the Nigerian climate [30].

The first nine items are scored on a five-point scale (1=no activity, 5=highest activity), and they are used to calculate the PAQ-C summary score. Items 1 (spare time activity) and 9 (PA throughout the week) are presented as composite scores, which are composed of the means of all activities. A PAQ-C summary score of ≤ 2 was interpreted as "low activity," >2 and ≤ 3 as "moderate activity," and >3 was interpreted as "high activity" [30].

5.3.6 Shuttle Run Test

The 20 m shuttle run test (SRT) was used to assess the aerobic capacity of the children [33]. The test is valid and easy to administer. The participants ran back and forth a 20 m distance to the beep that increased as the test progressed, and the test ended when the children could not run anymore or until they failed to reach the line twice within the appropriate time [34]. The cardiorespiratory fitness was analyzed based on the total number of shuttle laps completed and the estimated VO_2Max (31.025+3.238* (shuttle speed)-3.248*(age) + 0.1536*(shuttle speed*age)) [35].

5.3.7 The Pediatric Quality of Life Questionnaire

The Pediatric Quality of Life Questionnaire (PedsQL 4.0) was designed to measure the core health dimensions delineated by the World Health Organization (WHO) in both healthy and chronically ill children [36]. It is a valid multidimensional child self-report scale consisting of four domains (physical health, emotional, social, and school functioning) with a total of 23 items [36]. The questionnaire items are scored and linearly transformed to a 0–100 scale. The total scale score is the sum of all the items over the number of items answered on all the scales. Higher scores indicate a better quality of life [36].

5.4 Data analysis

The data were visually inspected via boxplots and a normal Q–Q plot. Values with a z score greater than 3 or less than -3 were removed. In the 1st-year dataset, based on this criterion, we removed four outliers from the SRT, one from the spare time activity checklist of the PAQ, one from the PedsQL and one from the CALI21. In the 2nd year, we removed two outliers from the SRT and one from the PedsQL. In the 3rd year, we removed four outliers from the PedsQL. In addition, children with incomplete questionnaire results were not included in the data analysis. Descriptive statistics were summarized via either frequency tables or means. The data

were reported on the basis of three classifications for the total Beighton score. For the first year, a more detailed analysis was performed on the total scores and subscores of the questionnaires to examine group differences (n=164) via ANOVA.

For the longitudinal analysis (n=111), a mixed model repeated measures design was used, with time (3 levels) as the within-subject factor and group (3 levels of mobility) as the between-subject factor. In the case of significant effects, post hoc pairwise comparisons are reported with Bonferroni correction. P values less than 0.05 (two-tailed) were considered statistically significant. Effect sizes are reported as eta squared (η^2) and interpreted as small (0.01), medium (0.06), or large effects (0.14). The data were analyzed via SPSS version 29.

5.5 Results

5.5.1 Baseline results

5.5.1.1 Demographic data

The study started with 165 children (76 males, 89 females). The demographic distribution per mobility group is presented in Table 5-1. No differences in sex distribution, age or BMI were found between the joint mobility groups.

Table 5-1 : Participants' demographic and joint mobility distributions in year one.

Demography	Normal Mobile Beighton 0-4	Mobile Beighton 5-6	Hypermobile Beighton 7-9	Statistics	p value
Gender N (%)				χ =2.840	0.242
Male	37 (52.9)	24 (44.4)	15 (36.6)		
Female	33 (47.1)	30 (55.6)	26 (63.4)		
Total	70 (42.4)	54 (32.7)	41 (24.8)		
Age mean (SD)	7.64 (0.90)	7.56 (0.79)	7.59 (0.84)	F=0.168(2,162)	0.845
BMI mean (SD)	14.68 (2.35)	14.53 (2.06)	14.68 (2.88)	F=0.077(2,162)	0.929

N=number of participants. SD= Standard deviation

Outcomes

The statistics for the comparison at baseline for the joint mobility groups are shown in Table 5-2.

5.5.1.2 Level of Pain

In this study, 6% of the children reported pain, however this was unrelated to joint mobility (χ=4.02, p=0.404); details are presented in Table 5-2.

5.5.1.3 Child Activity Limitation Interview

The differences in functional difficulties between the joint mobility categories did not reach significance (F(2,161) 2.34, p=0.10) (Table 5-2)**.**

5.5.1.4 Physical Activity Questionnaire for Children (PAQ-C)

The total PA score did not differ between the groups (see Table 5-2). Moreover, no significant difference emerged between their spare time activity checklist scores for the joint mobility groups (F(2,159)0.148, p=0.863). Weekly PA was also not different between the mobility groups (F(2,161)1.216, p=0.299).

5.5.1.5 Shuttle Run

The joint mobility categories significantly differed (p=0.008) in total number of shuttle laps covered and estimated VO_2Max (p= 0.016). The details are presented in Table 5-2. The post hoc analysis revealed that the mobile children ran significantly more shuttle laps and had higher estimated VO2max values than the children with normal mobility (see Table 5-3 for post hoc).

5.5.1.6 Pediatric Quality of Life Inventory (PEDSQL 4.0)

The differences in overall quality of life between the joint mobility categories did not reach significance (F(2,163) 2.68, p=0.07). When we looked in more detail at the four domains of the PedsQL, a significant difference in the physical health functioning domain was found (F(2,164) 4.55, p=0.012). The post hoc pairwise comparison test revealed that the mobile group had significantly greater physical health functioning than the children with normal mobility (p=0.01); details of the post hoc analysis are presented in Table 5-3.

Table 5-2: Baseline comparison of joint mobility (3 categories), CALI-21, PAQ-C, SRT, and PedsQL.

Variable	Normal Beighton 0-4	Mobile Beighton 5-6	Hyper Mobile Beighton 7-9	F (df) -value	p value	Partial eta squared
Pain intensity N (%)				4.04#	0.404	
0	63 (90)	52 (96.3)	40 (97.6)			
2	3 (4.3)	1(1.9)	1(2.4)			
6	4 (5.7)	1(1.9)	0 (0)			
CALI-21 Mean (SD)	24.53(10.66)	20.54(10.84)	21.58(10.03)	2.337(2,161)	0.100	0.029
PAQ-C Mean (SD)						
PAQ summary score	2.86 (0.51)	2.80 (0.50)	2.69 (0.44)	1.567(2,160)	0.212	0.019
Spare time activity	2.28 (0.56)	2.22 (0.55)	2.26 (0.55)	0.148(2,159)	0.863	0.002
PE activities	3.29 (0.93)	3.36 (0.90)	2.99 (0.81)	2.119(2,161)	0.123	0.026
Weekly activities	3.58 (0.93)	3.47 (0.83)	3.31 (0.87)	1.216(2,161)	0.299	0.015
SRT Mean (SD)						
Total shuttle laps	9.38 (5.62)	13.23 (8.03)	10.68 (6.29)	5.006(2,160)	0.008*	0.060
Estimated VO_2Max	45.31 (2.45)	46.52 (2.27)	45.57 (2.22)	4.220(2,160)	0.016*	0.051
PedsQL Mean (SD)						
Total score QoL	76.81(13.00)	82.01(11.14)	78.45(13.60)	2.684(2,163)	0.071	0.032
Physical Health	80.71(14.61)	88.31(13.38)	82.55(16.67)	4.500(2,163)	0.012*	0.053
Emotions	72.97(15.54)	79.29(14.09)	74.15(17.09)	2.657(2,163)	0.073	0.032
Social	78.33(15.83)	79.91(16.06)	76.58(16.71)	0.496(2,163)	0.610	0.006
School	72.89(17.69)	77.04(16.35)	78.05(17.09)	1.496(2,163)	0.233	0.021

N=number of participants. # χ^2

Table 5-3 : Post hoc pairwise comparison of significant group effects at baseline.

Variable	Joint mobility group	Mean difference	P value
Total shuttle laps	Normal- Mobile	-3.84	0.006*
	Normal - Hypermobile	-1.29	0.996
	Mobile - Hypermobile	2.55	0.208
Estimated VO_2Max	Normal - Mobile	-1.21	0.016*
	Normal - Hypermobile	-0.26	1.000
	Mobile - Hypermobile	0.95	0.159
Physical health functioning	Normal - Mobile	-8.22	0.010*
	Normal - Hypermobile	-2.46	1.000
	Mobile - Hypermobile	5.76	0.206

*= $p<0.05$

5.5.2 Longitudinal results

No differences were found in the demographic data of the children who were lost to follow-up (n=54) and the children who remained in the study (n=111).

5.5.2.1 Demographic data

At the 3rd measurement, the participants' mean age was 9.56 (0.86) years, and their BMI was 20.14 (3.35). BMI did not differ between the groups (F (2,107) 0.933, p= 0.397). Over time, BMI increased significantly (F (2,106) 223.57, p= 0.001), but there was no interaction effect of time with group (F (4,214) 0.763, p=0.55).

5.5.2.2 Levels of pain over time

The children's level of pain decreased over time. In the 2nd measurement, 2.8% of the children (two normal mobile and two mobile) reported pain of intensity 2 on the FACES pain scale, and 97.2% reported no pain. None of the children reported pain in the 3rd measurement.

5.5.2.3. Child Activity Limitation Interview over time

According to the longitudinal analysis, the mobility groups did not differ in terms of functional difficulty (F(2,90)1.014 p=0.367), details are shown in tables 5-4 & 5-5. The children demonstrated a significant decline in functional difficulties over the years (implying that they improved) (F (2,89) 32.23, p<0.001); the pattern was similar among the groups; hence, there was no interaction of time with group (F(2,89)1.014 p=0.367); see Figure 5-2.

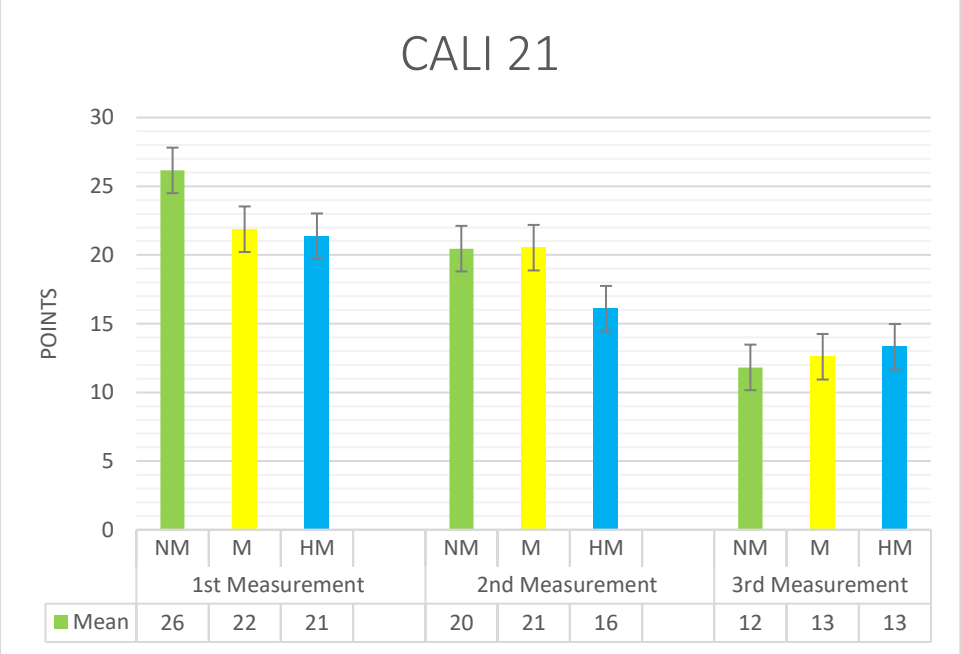

Figure 5-2: Functional difficulties over the measurements among the joint mobility groups, lower scores indicate fewer problems. Children perceived fewer problems over the measurements, but no group differences. Error bars depict the standard deviation.

5.5.2.4 Physical Activity Questionnaire for Children over time

A main effect of group was found for the PA levels (F(2,91)5.46, p=0.006) for means the statistics see Tables 5-4&5-5; children with hypermobility had significantly lower PA levels than children with normal mobility (for post hoc analysis see Table 5-6). For the total score of the PAC-Q, there was no main effect of time (p =0.70); see Figure 5-3.

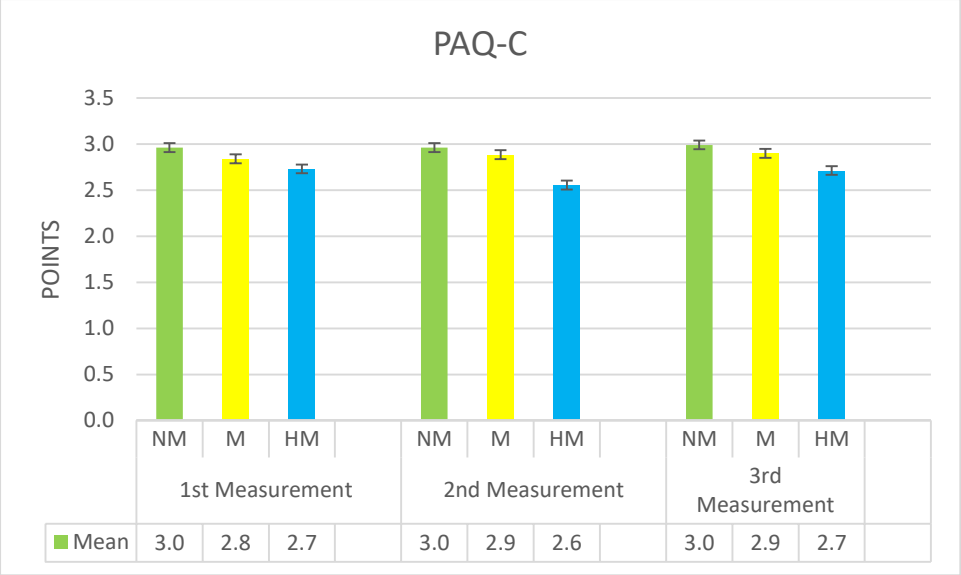

Figure 5-3: Physical activity levels over the measurements among the joint mobility groups. The level of activity did not change over the measurements. Hypermobile children were the least active. Error bars depict the standard deviation.

We also found a main effect of group on the spare time activity checklist; children with normal mobility engaged more in spare time activities than did children with GJH (F(2,91) 4.54, p= 0.013). Over time, all groups became less active during PE classes, and again, children with hypermobility were the least active during the PE class. Notably, PA levels during spare time increased significantly over time (F(2,90)14.62, p<0.001). PA levels during recess, lunchtime, and after-school activities decreased over time (F(2,96) 9.18, p<0.001), as did children's weekly level of PA (F(2,95)17.97, p<0.00). No time-by-group interaction emerged for any of the activity outcomes.

5.5.2.5 Shuttle Run test over time

There was no main effect of group on the total number of shuttle laps, as shown in Table 5-5 (F(2,97) 2.08, p=0. 130). Over time, the total number of shuttle laps the children could run before exertion increased (F(2,96) 4**T**.51, p=0.013; details in Tables 5-4&5-5) and groups were not different by the end of the study.

Moreover, the mean estimated VO2max, taking body mass and age into account, significantly decreased over time (F(2,96) 50.60, p=0.001), as presented in Figure 5-4. No interaction of time with mobile groups occurred. The difference observed in year 1 between the mobility groups was no longer significant in the subsequent measurements; details are presented in Tables 5-4&5-5.

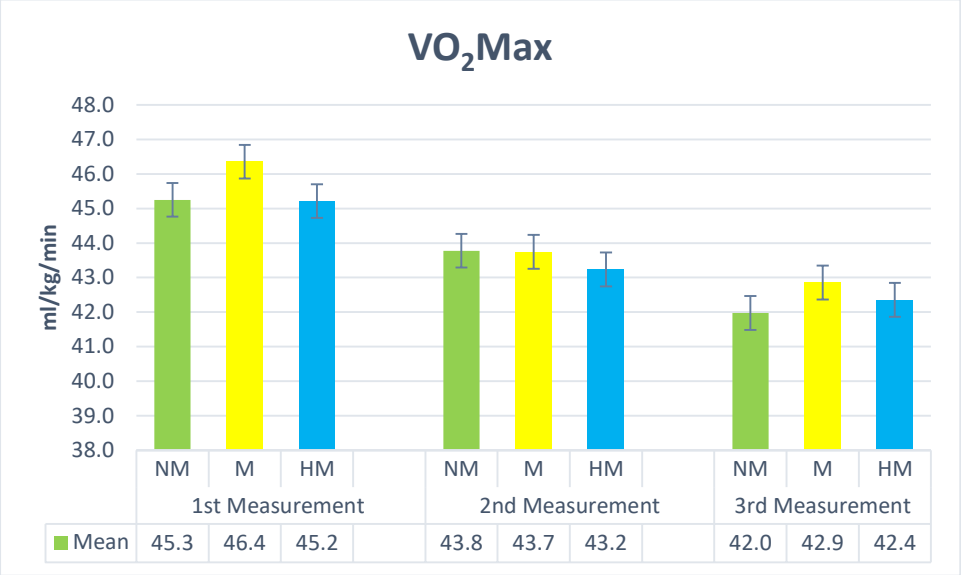

Figure 5-4: Estimated VO_2Max over the measurements. VO_2Max went down over the 3 measurements. No differences between the joint mobility groups. Error bars depict the standard deviation.

5.5.2.6 Pediatric quality of life questionnaire over time

The *overall QoL* did not differ between the mobility groups (F(2,92) 2.016, p=0.139). A main effect of time was found (Figure 5-5), with a significant increase in QoL over time (F(2,91)6.15, p=0.003) see Tables 5-4&5-5, and no interaction effect of time with group was observed (F(2,96) 1.257, p=0.315).

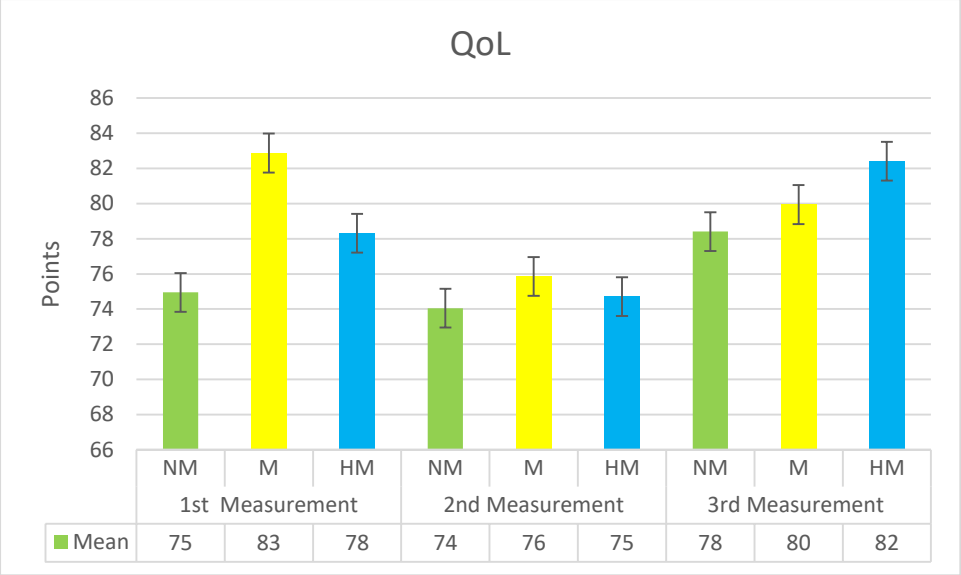

Figure 5-5: Overall QoL over the measurements among the joint mobility groups. QoL was lower at measurement 2 compared to measurements 1 and 3. No differences between the joint mobility groups. Error bars depict the standard deviation.

The *physical health* scores were not different between the mobility groups (F(2,92) (0.41, p= 0.665), details in tables 5-4&5-5. However, the scores increased significantly over the years (F(2,91)12.07, p=0.001; see Figure 5-6); however, scores at measurement 2 were lower than those at measurements 1 and 3. There was a significant interaction effect of time with group (F(4,184)3.149, p=0.005). This was caused by the fact that the changes over time were dissimilar for the 3 mobility groups; in normal mobile children, measurements 1 and 3 were different (increase); in mobile children, measurements 1 and 2 were different (decrease); and in hypermobile children, measurements 2 and 3 were different (increase).

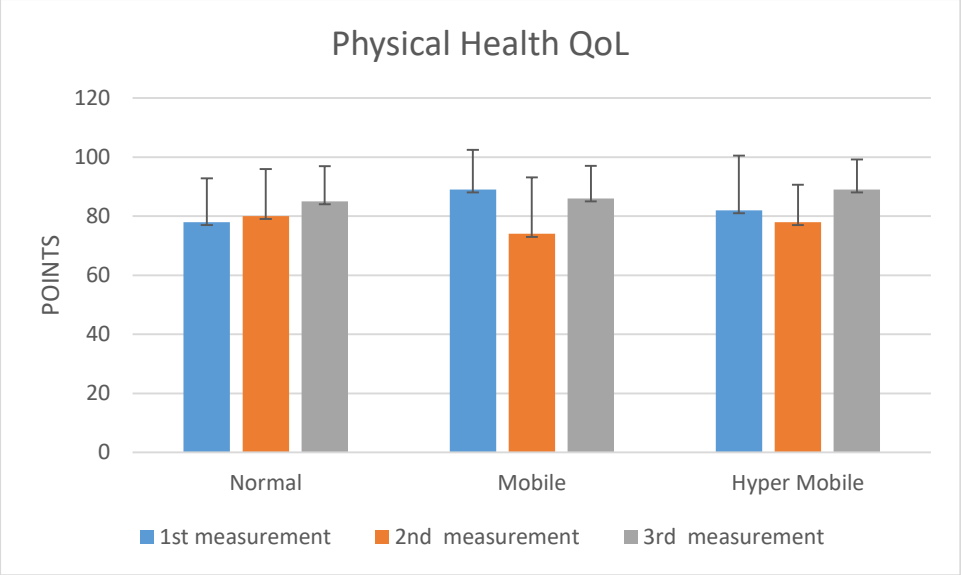

Figure 5-6: Physical Health QoL over the measurements among the joint mobility groups. Error bars depict the standard deviation.

The outcomes on the *emotions subscale* of the QoL did not differ between the mobility groups (F(2,94) 1.52, p=0.224); details are presented in Table 6. We found an effect of time that demonstrated a significant decline in emotional QoL; that is, the children demonstrated more negative emotions (F(2,93)4.36, p=0.015), and this difference was significant between measurements 1 and 2 (p=0.004). No time-by-group interaction was found (F(4,184) 0.694, p=0.597).

For *social QoL*, there was no group effect (p=0.19) or time effect (F (2,93) 0.714, p=0.492) and no time-by-group interaction (F (4,188) 0.382, p=0.822).

The *school functioning* domain did not differ between the groups (F(2,93)0.32, p≤0.730). There was a significant increase in school functioning over time (implying that they had fewer problems with school activities) (F(2,92)7.04, p≤0.001). The differences were significant between measurements 1 and 3 (p=0.003) and between 2 and 3 (p≤0.001), indicating the highest values in the 3rd measurement (see Tables 5-4&5-5). There was no time-by-group interaction (F (4,186) 2.244, p=0.066).

Table 5-4: Means (SD) for the variables per mobility group and per measurement for functional difficulties (CALI21), PA (PAC-C), shuttle run test, and QoL (PedsQoL).

Variable	Normal Beighton 0-4	Mobile Beighton 5-6	Hyper Mobile Beighton 7-9	1st Measurement	2nd Measurement	3rd Measurement
CALI21#	19.48(7.34)	18.33(6.49)	16.92(6.04)	23.55(10.45)	19.45(15.02)	12.44(8.72)
PAC-C						
PAQ total	2.97(0.35)	2.88(0.35)	2.67(0.34)	2.87(0.49)	2.84(0.61)	2.89(0.61)
Spare time activity	2.81(0.46)	2.70(0.39)	2.47(0.44)	2.31(0.59)	2.86(0.82)	2.89(0.81)
PE activity	3.09(0.49)	3.08(0.46)	2.78(0.49)	3.31(0.89)	2.84(0.69)	2.89(0.76)
Weekly activity	3.07(0.59)	3.06(0.62)	2.95(0.44)	3.53(0.88)	2.71(0.97)	2.87(0.92)
Shuttle run						
Total shuttles	9.96(5.19)	12.39(6.30)	10.18(4.66)	10.19(6.07)	9.8(6.47)	12.53(10.33)
Vo2max	43.67(2.10)	44.32(2.05)	43.60(1.32)	45.62(2.10)	43.70(2.60)	42.45(3.05)
PedsQL						
Overall QoL	75.80(8.46)	79.56(8.10)	78.48(7.86)	78.48(13.21)	74.83(13.33)	79.87(9.91)
Physical health	81.14(9.69)	82.66(9.0)	83.19(9.44)	82.86(15.80)	77.33(16.60)	86.28(11.22)
Emotion	69.0(11.90)	73.63(11.94)	70.15(10.54)	74.48(14.85)	67.06(18.82)	71.13(17.51)
Social	74.06(9.31)	78.19(9.39)	76.59(10.97)	77.87(16.34)	75.05(16.82)	75.38(15.66)
School	69.0(11.90)	73.63(11.94)	70.14(10.53)	75.57(16.92)	75.78(18.03)	82.66(13.44)

Table 5-5 : Main effects of mobility group and time on the following variables: functional difficulty (CALI21), PA (PAC-C), shuttle run test score, and QoL (PedsQoL).

	Main effect of group			Main effect of Time		
Variable	F (dF) value	p value	Partial eta squared	F (dF) value	p value	Partial eta squared
CALI21#	1.014(2,90)	0.367	0.022	32.23(2,89)	**0.001**	0.420
PAC-C						
PAQ total	5.46 (2,91)	**0.006**	0.107	0.40 (2,90)	<0.669	0.009
Spare time activity	4.54 (2,91)	**0.013**	0.091	14.61(2,90)	**<0.001**	0.245
PE activity	3.67 (2,97)	**0.029**	0.070	9.18 (2,96)	**<0.001**	0.161
Weekly activity	0.34 (2,69)	0.711	0.007	17.97(2.95)	**<0.001**	0.274
Shuttle run						
Total shuttles	2.08 (2,97)	0.130	0.041	4.51 (2,96)	**0.013**	0.086
Vo2max	1.45 (2,97)	0.239	0.029	50.59(2,96)	**<0.001**	0.513
PedsQL						
Overall QoL	2.62 (2,92)	0.139	0.042	6.15 (2,91)	**0.003**	0.119
Physical health*	0.41 (2,92)	0.665	0.009	12.07(2,91)	**<0.001**	0.210
Emotion	1.52 (2,94)	0.224	0.031	4.36 (2,93)	**0.015**	0.086
Social	1.69 (2,94)	0.191	0.035	0.71 (2,93)	0.492	0.015
School	0.32 (2,93)	0.730	0.007	7.04 (2,92)	**0.001**	0.133

#Lower scores indicate less functional difficulties. * Interaction time by mobility group (F(4,184)3.149, p=0.005).

Table 5-6 : Post hoc analysis of the main effect of group on the physical activity level outcomes.

Variable	Joint mobility Groups		Mean difference	p value
PAQ TOTAL	Normal	Mobile	0.097	0.716
	Normal	Hypermobile	0.31	0.004*
	Mobile	Hypermobile	0.21	1.96
SPARE ACTIVITY	Normal	Mobile	0.11	0.893
	Normal	Hypermobile	0.34	0.010*
	Mobile	Hypermobile	0.24	1.44
PE ACTIVITY	Normal	Mobile	0.01	1.000
	Normal	Hypermobile	0.31	0.042*
	Mobile	Hypermobile	0.03	0.063

* $p<0.05$.

5.6 Discussion

The objective of our study was to determine the level of pain among our study population and the impact of hypermobility on functional difficulties, levels of physical activity, and quality of life over two years. At baseline, the mobile children (Beighton score 4 and 5) performed better on total shuttle laps, estimated VO_2Max and the physical health functioning part of the PedQoL, with medium to small sizes (η^2 0.06, 0.05, 0.05).

The longitudinal data showed that the included children perceived less functional activity limitations and an improvement in their overall QoL (PedsQoL) over the measured period. Additionally, their aerobic fitness decreased between the start and the end of the study. Importantly these changes were comparable for the three joint mobility categories. The only outcome where group differences were found was the levels of physical activity (PAC-C), with a medium effect size (η^2 0.11). Children with hypermobility had significantly lower PA levels than children with normal mobility. The differences we found at baseline in total shuttle laps and estimated VO_2Max were no longer there at the end of the study.

Contrary to the literature, we did not find a difference in functional activity limitations, and QoL between the joint mobility categories throughout the study. Our longitudinal data has provided evidence that the development of children with GJH is not different from children with normal mobility because we did not find interactions of groups by time on any of our main outcomes.

In contrast to the present findings, the argument in the literature has been in the direction of functional difficulties in children with GJH, based on the assumption that their abnormal joint biomechanics make their joints unstable, thus increasing the incidence of pain and injuries that lead to activity limitations and functional difficulties [37,38]. We have possible alternative explanations for our findings. First, the children with GJH in our study remained asymptomatic; hence, there was no difference in functional difficulties between them and the children with normal mobility [39]. Secondly, Connelly et al 2014, suggested that the ability of individuals with GJH to cope with presence of pain needed to be explored because it could be a possible explanation for the comparable quality of life between them and their normal mobile counterparts [40]. Avoidance behavior has been identified as one of the coping strategies in individuals with GJH [41]. This helps them to prevent injuries and avoid the risk of musculoskeletal symptoms. Lastly, the outcome

of our study can also be interpreted based on cultural influence on physical activity, as previous authors have highlighted functional difficulties in children with GJH from studies done in Western countries [42,43]. Evidence in the literature has shown that most Nigerian children get their physical activity in school and this is attributed availability of sports facilities so that extra mural activities take place more in school than in the communities or homes [44]. Despite the fact that our study location was in an urban setting, our study population came from the low socioeconomic class, with low levels of structured active leisure time. However they make up for their lower structured physical activity level by the need for active transportation to school (walking). Environmental factors such as increased land use mix, good aesthetics and improved hygienic qualities of neighborhoods and safety from crime and traffic has been identified is an important determinant of participation in physical activity by Nigerian adolescent [45].

Previous authors have concluded that there is a need for longitudinal studies to provide more insight into PA patterns in children with GJH as they grow older, especially with reports of reduced levels of PA in late childhood [1,46]. To our knowledge, the current study provides the first longitudinal data on PA in children with GJH in this age range (6-9 years at measurement 1 and 8-11 years at measurement 3). At the end of our study, we found a significant difference in PA levels between the joint mobility groups. The post hoc analysis revealed that highly mobile children had a significantly lower level of PA than children whose mobility was within the normal range. The outcome of our study also suggests that a three-level classification of joint mobility provides more details on the impact of joint mobility on PAs than a two-level classification.

Psychosocial traits such as anxiety and fear avoidance are also disabling symptoms that can grossly affect PA [47]. It is assumed that children with GJH may avoid vigorous-intensity PA activities because of their consciousness of their joint flexibility. In addition, it is not known whether pressure for performance can induce anxiety in children with GJH, causing avoidance and subsequently lower levels of physical fitness [47]. These lower PA levels are of concern because of the long-term effect on health outcomes [7]. A consideration for future studies could include a longer follow-up on PA in highly mobile children to determine whether increased mobility and decreased PA lead to complaints and limitations when children get older. A more detailed analysis

of the subscales of the PAC-C revealed some extra insights. Throughout the study, PA during spare time increased significantly over time, while PA levels during PE, recess, and after-school activities decreased significantly, however, these changes were comparable for the three groups. This outcome suggests that sedentary behavior is reinforced more in school than at home. Even though we did not gather information on the time allocated by schools for PE, recess or after-school activities, it is likely that with increasing academic demands as children advance in class, break time is just enough for eating and little physical activity. School is an important social environment for a child, and it contributes to a child's overall QoL. Importantly, the emphasis should be not only on academic activities but also on PA during school hours [48]. Interestingly, although overall levels of PA during PE and spare time were lower in children with hypermobility, their reported frequency of being active during the week was not ($p=0.711$).

The mean estimated VO_2max was different between the mobility groups at baseline but not at the end of the study. As expected, physical fitness levels (VO_2Max) among the study population declined over time, which was in line with the decline in PA [8]. The groups became more equal, which might have been caused by less PE and more sedentary behavior for all the children. This outcome negates our assumption that children with GJH who are trying to protect their hypermobile joints will perform less PA, as this would have reduced their physical fitness more than in children with normal mobility [49].

Overall QoL was not different between the mobility groups at baseline or at follow-up. The only domain (physical health QoL) where we found a difference between the mobility groups at the beginning of the study was not different at follow-up. Considering that functional difficulties were not different between the mobility groups, it is therefore not surprising that their QoL did not differ. Interestingly, the mobility groups did not differ in terms of school-functioning QoL because challenges with handwriting and difficulty coping with schoolwork have been documented as features of GJH [50,51]. The increase in school functioning could be a result of provisions of incentives by the school authorities to facilitate learning. An alternative explanation for the extra appreciation of school quality of life could be that it was related to the Coronavirus Disease 2019

(COVID-19) lockdown restrictions. This would fit with the dip in QoL in the second year for social and emotional quality of life for all the groups (2022 data) [52].

Study limitations and strengths

The longitudinal design of this study makes it possible to evaluate developmental changes. The PAQ provides detailed insight into children's PAs, both at home and at school. The outcome of PE activities has added to the body of evidence supporting the relevance of PA during and after school hours. The inclusion of an activity diary in our study could have given insight into other activities the children were involved in apart from the spare time activity in the checklist of the PAQ. The PedsQL tool is a health-related and valid measure of an individual's health status. However, questionnaires provide insight into the perceived QoL and PA, and the actual level of physical activity was not measured. The inclusion of personal PA diaries for more details on PA not captured in the PAQ-C is a consideration for future studies. Lastly, previous studies have attempted to link developmental coordination disorder (DCD) and hypermobility due to the overlap of symptoms, and both conditions are highly prevalent among school-aged children [53,54]. A recent review of the literature suggested that hypermobile children with handwriting difficulty may also be diagnosed with DCD [54]. No data are available if any of the children with GJH in the present study have comorbid DCD.

5.6 Conclusion

Our longitudinal data confirmed that the presence of GJH has no negative effect on functional activities, physical fitness or QoL. Our study does provide evidence that children with hypermobility are less physically active. Even though the overall score for PA differed between the mobility groups at follow-up, the PAQ subscore for how often the children were active during the week did not differ. Nevertheless, school management should encourage students' participation in PA and PE during school hours, as the school environment has been identified as a suitable place to promote positive health behaviors [55].

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Chapter 6: Discussion & Conclusion

6.1. Summary of Key Questions

In the first year of this present study, the prevalence of joint hypermobility (localized, peripheral and Generalized JH) among our sample population was determined. The study also determined if proprioception, dynamic balance, and muscle strength were different between children with GJH and children with normal mobility. Lastly, the impact of joint mobility on physical activities, functional difficulties, physical fitness, and quality of life in school-aged children in the longitudinal part of the study was investigated.

6.2. Prevalence of Joint Hypermobility.

This present study presented the second published data set on the prevalence of joint hypermobility among Nigerian children. The first published prevalence study on joint mobility included adults and children classified as hypermobile with a Beighton score of ≥4. The implication of the low cut-off is a possible overrepresentation of GJH in that sample [90]. It is believed that hypermobility is a normal variant among children, so it was suggested that a higher Beighton score cut-off, specifically ≥6, will give a truer representation of GJH among the study population [9,28]. One of the determinants of the prevalence of GJH is the Beighton score cut off used for the classification of GJH, so in this present study, the Beighton score cut off of ≥5 and ≥7 were used for the classification of GJH [103]. In addition, several authors in the field have called for the use of higher Beighton score cut off for the classification of GJH in children who are predominately hypermobile [91,104]. This call is to prevent an overrepresentation of GJH in children.

In this present study, joint mobility was presented in three categories, namely normal mobile, mobile and hypermobile [14], to possibly explain if the number of hypermobile joints will have any association with musculoskeletal symptoms.

The findings of this present study revealed the following:

1) The prevalence of GJH dropped from 37.4% using a Beighton cut off of ≥5 to 27.3% using a Beighton cut off of ≥7.

2) Children with a Beighton score of 5-6 had higher physical activity levels than those with a Beighton score of ≥7.
3) Children with a Beighton score of 5-6 had higher physical fitness levels than those with a Beighton score of ≥7
4) Children with a Beighton score of 5-6 had better overall quality of life than those with a Beighton score of ≥7

Apart from the prevalence of GJH, the data on prevalence of localized and peripheral hypermobility was also presented because data concerning these aspects of JH are scarce. It has been highlighted that the presence of Peripheral Joint Hypermobility (PJH) may be a clue to the presence of Vascular Ehlers–Danlos Syndrome (EDS) [31,88].

The study had 14.9% of the children classified as normal mobile also presenting with Localized Joint Hypermobility (LJH), specifically at the 5^{th} metacarpophalangeal (MCP) joint. This interesting finding opens a direction for future studies because children with LJH are at risk of developing musculoskeletal symptoms [20].

Joint hypermobility is a consequence of ligamentous laxity that increases joint flexibility that can promote motor performance but also increase the risk of injuries [80]. Due to conflicting evidence, the role joint hypermobility plays in onset of musculoskeletal symptoms in GJH is still being investigated. Some authors have suggested that the degree of hypermobility and not just its presence may be a possible indication of the onset of injuries [27]. In the present study, the inclusion of goniometry increased the sensitivity of the Beighton scoring system in the identification of GJH. Thus ensuring a more accurate depiction of severity of hypermobility.

The inclusion of goniometry in the assessment of joint Range of Motion (ROM) in this present study was to also document the degree of hypermobility and not only the presence of hypermobility, which the dichotomous value of the Beighton score offers [105]. From the outcome of this present study, 185 children were classified as hypermobile, 3 (3.6%) had 20^0 ROM hyperextension in the right elbow joint and 5 (6.4%) in the left elbow joint. The degree of hypermobility has been reported to be correlated with pain intensity in individuals with hypermobile EDS [106]. This needs to be explored in children with GJH as a possible link to musculoskeletal pain [106]. In addition, for follow-up studies goniometric measurement will be

more sensitive to change in mobility status. This will allow to determine whether loss of joint mobility is faster in individuals with a higher degree of hypermobility.

6.3. GJH, Strength and Dynamic Balance.

To identify the factors that may modulate the onset of musculoskeletal symptoms in GJH it was important to measure strength and balance in children with GJH and compare their outcomes with those of children with normal mobility. Reduced strength has been associated with GJH, even though most studies have evaluated isometric strength [69,107]. The isometric measure of strength cannot be used to interpret how children with GJH utilize strength in their functional activities because it does not reflect the dynamic movements necessary for activities of daily living (ADL) [74]. If strength is required for activity participation then measurement of functional strength will be preferable when investigating deficits [80]. Laxity of connective tissues provides flexibility that has been reported to enhance motor performance as seen in activities such as gymnastics and, swimming. Notably injuries are more likely to occur during dynamic movements than static or stationary positions, highlighting the importance of assessing strength in a dynamic context. According to the International Classification of Functioning, Disability and Health (ICF) structural impairments as seen in GJH can impact an individual's function, activity and participation in daily life.

This study is the first to use the FSM to assess muscle function (endurance, strength and power) in children with GJH and of particular interest is the stair climbing task. Bates et al 2022 suggested that stair-climbing is a task that can be used to identify impairment in hypermobile individuals because it demands more than level walking and the challenge can be further compounded by muscle weakness and impaired balance. In this first study on FSM in children with GJH, children with GJH were significantly better than children with normal mobility in the lower limb items except the stair climbing task. This suggests stair climbing as a possible precursor of musculoskeletal symptoms in GJH**.**

The Functional Strength Measurement (FSM) comprises upper and lower limb activities. This present findings revealed no difference in the upper limb items (details are presented in table 3-4) and stairclimbing activities ($p=0.19$) but children with GJH had significantly better scores in the other lower limb activities. Stair climbing is considered a demanding task and requires quick stabilization of the lower limb joints [108]. Individuals with lax ligaments are more likely to

depend on fast muscle activation to achieve stabilization [27,96]. The data from this study has provided evidence of the compensatory muscle activity in GJH that has enabled them to be effective in their motor functions. Previous electromyography studies have confirmed over activity of muscles in children with GJH when compared with children with normal mobility [7,71,109].

The association was also investigated between strength and dynamic balance because good muscle strength is necessary to maintain excellent dynamic balance [110]. We found a moderate correlation between FSM lower limb items and dynamic balance (r=0.256). Interestingly, there was a strong correlation between reaching distance in the Y-balance and the explosive power items of the FSM (r=0.366).

6.4. GJH and Proprioception.

Proprioceptive deficit has been considered the most common feature of HSD because it is assumed that ligamentous laxity is synonymous with instability which poses a risk to the joint mechanoreceptors [111]. There has been weak evidence supporting proprioceptive deficit in HSD, yet the role joint laxity places in impaired proprioception is still not clear because of the different test tools and positions used in previous studies [94]. The use of the Wedges test in this study is based on the recommendation of the review of methods by Han 2016, who advocated that tests of proprioception should reflect real world scenarios. The Wedges test was used by Ituen et al (2020) to test proprioception in the loaded position and it was found that proprioception was not impaired in children with GJH [53]. Their outcome has been confirmed in this present study, even after the inclusion of smaller heel height differences (to make the task more difficult) (F (1,148) 0.15, p=0.70). Proprioception was tested in the weight-bearing and non-weight-bearing positions, and the outcome from this present study confirmed the superiority of loading in tests of proprioception because participants made fewer errors in the weight-bearing than in the non-weight-bearing position [94].

It is noteworthy that in either test position, proprioception was not impaired in children with GJH nor were the results of the joint repositioning test to evaluate proprioception in the upper limb (F1,147 =0.00, p 0.992). The outcome of this present study did however revealed an oblique effect, the participants recorded the least repositioning error at the cardinal orientations (90^0) [112].

Participants in this present study made less errors repositioning the non-preferred than the preferred side although the difference was not significant (F(1,147) 1.090, p= 0.298). This needs to explored in future studies because the non-preferred side is usually more hypermobile than the preferred side [72]. The lack of correlation between the wedges used for the lower extremity and the joint reposition test used for the upper extremity confirms that these are independent assessment of proprioception [51].

6.5. GJH and Quality of Life.

We presented the results on GJH, physical activity level, physical fitness, functional difficulties and QoL at three time points. Joint mobility was classified based on three categories, that is normal mobile (Beighton score 0-4), mobile (Beighton score 5-6) and hypermobile (Beighton score 7-9). The purpose of this was to demonstrate how the magnitude of joint mobility based on their Beighton scores affects the outcome of functional difficulties, physical activity, physical fitness and QoL.

At the first measurement, the children's pain intensity was not related to joint mobility. Interestingly, more children with normal mobility (6%) reported pain than children with GJH. By the third measurement, none of the children reported pain at any joint. Children with GJH in this present study remained asymptomatic throughout the study. The finding that our cohort remained asymptomatic throughout the study period may not be unusual because our cohort were from a healthy population without an established diagnosis of HSD. Even though there has been discussions in literature regarding the influence of culture differences on pain, Nortjé & Albertyn 2015 argued that children’s expression of pain may not be influenced by culture because at their age they do not have preconceived ideas like adults [113].

At baseline, there was a significant difference in the study participants’ physical fitness and physical health QoL domain. The post hoc result revealed that mobile children ran significantly more shuttle laps (p=0.006) and had higher estimated VO2max (p=0.016) values than the children with normal mobility. Interestingly, the children with GJH who were mildly mobile recorded higher VO_2Max values than those who were highly mobile. Similarly, the mobile group had

significantly greater physical health functioning (p=0.010) than the children with normal mobility. This suggests that a certain degree of extra flexibility may be beneficial.

From the longitudinal result, all outcomes did not change between groups except the physical activity levels. Physical activity was comparable over the years but was significantly different between the groups showing the impact of joint mobility status. Again the children who were mobile recorded higher activity levels than the hypermobile ones. Additionally, for this present study, the collection of data after the lockdown. Even though schools reopened restrictions on the children gathering in the school assembly and playground during lunch were maintained. As a result, their physical activities in school was reduced. However, we did not collect data on their Covid-19 status or physical activity level after school hours.

The findings from the longitudinal results of this present study are contrary to opinions in literature because functional difficulties decreased over the years, implying that even children with GJH performed better in their functions over the years [114]. In this case it was the highly mobile group that showed the least functional difficulty at the end of the study. Overall the QoL between the groups was not different but it is noteworthy that children with GJH had higher mean scores indicating better QoL than their normal mobile counterparts (F(2,92) 2.016, p=0.139). Interestingly, despite handwriting difficulties associated with hypermobility, children with GJH recorded higher mean scores on school functioning than those with normal mobility (F(2,93)0.32, p≤0.730) [10,59]. This result clearly shows that close attention needs to be paid to children who have very high Beighton score, even though the highly mobile children (Beighton score 7-9) had lower functional limitations (see figure 5-2), the children with mild mobility (Beighton score 5-6) showed higher physical activity levels, which over time might lead to difference in their motor functions (see figure 5-3).

Ligamentous laxity allows for joint flexibility but it also makes the joint biomechanics abnormal making the joint susceptible to instability and repetitive trauma. Previous cross sectional studies have reported motor difficulty in children with GJH but have not been able to conclude how it affects their participation in physical activity, physical fitness and overall QoL overtime. This longitudinal study showed that despite the abnormal joint biomechanics, the children with GJH

had moderate level of physical activity, and were not different from the normal mobile children in physical fitness level and overall QoL. In this study, in order to evaluate the impact of multiple hypermobile joints, joint hypermobility was classified as mobile (Beighton score of 5-6) and hypermobile (Beighton score of 7-9). The children who were classified as mobile performed better than the children classified as hypermobile on all outcomes suggesting that it is easier to cope with a little bit of joint hypermobility.

6.6 Strengths and Limitations of the Study.

6.6.1 Strengths.

The longitudinal design of our study enabled us to investigate and establish a possible causal relationship between joint mobility and physical activity levels, physical fitness, and overall quality of life. Previous cross-sectional studies have not been able to conclude the role of joint laxity in the onset of musculoskeletal symptoms in GJH, because the effect of the micro and macro trauma is seen over time. Remarkably, the children with GJH in this study reported fewer functional difficulties and were fitter than children with normal mobility over time. This challenges the role joint laxity is assumed to play in the pathology of musculoskeletal symptoms**.**

The presentation of joint mobility in three categories demonstrated the magnitude of the hypermobility effect on the different study outcomes. Despite being classified as hypermobile, children with a Beighton score of 5-6 reported fewer functional difficulties than children with Beighton score of ≥7. The implication of this in future studies is that children with a Beighton score of ≥7 may be the cohort of children who develop musculoskeletal symptoms over time.

This present study presented the prevalence of localised and peripheral hypermobility, a type of data that is scarce in the literature. In addition, our inclusion of goniometric measurement gave more details than the dichotomous data of the Beighton scoring system. Our findings have clearly shown that an individual may be classified with normal joint mobility, but may still exhibit localised joint hypermobility characterised by an excessively large range of motion in a specific joint.

The assessment of functional strength in children with GJH has provided evidence for muscle activation in children with GJH. This evidence is the first published data on stairclimbing in children with GJH, and it fills the gap in the identification of impairments in GJH that justifies the effectiveness of therapy [115]. It is noteworthy that in this study, children with GJH performed better than the children with normal mobility on all lower limb items of the FSM except the stair climbing activity. Although they were not statistically different, the fact that their mean score was lower than that of their normal mobile counterparts suggests that stair climbing may be a precursor to identifying impairment in GJH.

This study significantly adds to the sparse literature on functional capacities in children with GJH, offering novel insights into stair-climbing, and box-lifting abilities, thus establishing a critical framework for future research and comparative analysis.

6.6.2. Limitations.

We had attrition of participants due to some participants changing school but we minimized this loss through follow-up assessments at their new schools for those within reach.

Some children missed the isometric muscle strength test due to equipment (the hand-held dynamometer) failing (HHD) at the time of their measurement. Nevertheless, the remaining sample size provided sufficient statistical power to support our outcome.

6.7 Recommendations.

6.7.1 Given the prevalence of localized and peripheral hypermobility in our study, it is important that joint hypermobility research should not be limited to GJH. This broad representation is needed because musculoskeletal symptoms can be present irrespective of the type of joint hypermobility.

6.7.2 The inclusion of goniometry is necessary for assessment of the degree of hypermobility because it provides extra detail on joint mobility not only in follow-up studies, but also in demonstrating the possible link between the onset of musculoskeletal symptoms and joint hypermobility. It is intriguing that despite being classified as normal mobile, one can still have an excess degree of movement in a joint which is larger than in a child

classified as hypermobile. In reality, the effect of hypermobility is pronounced during motor performance because the amount of strength and balance required to maintain stability in a joint with ROM of 15^0 will be greater than in a joint with ROM of 10^0. Using goniometry in this study we were able to identify children with excess ROM above the Beighton criteria of 10^0; this cohort included children classified as either normal mobile or GJH. It is quite intriguing that, despite being classified as normal mobile one can still have excess ROM in a joint, which is larger than in a child classified as hypermobile.

6.7.3 We recommend that authors present joint mobility in three categories to demonstrate the impact of the magnitude of joint hypermobility. A little bit of hypermobility is not a challenge. We therefore recommend a higher Beighton score (≥7) for the classification of GJH when investigating musculoskeletal symptoms.

6.7.4 The outcome of our study has provided evidence that measurement of strength using the Functional Strength Measure (FSM) is a better outcome not only because it is relatable to activities of daily living but it is cheaper than the hand-held dynamometer. In addition, the FSM measures various aspects of muscle strength. Muscular fitness is a combination of muscular endurance and explosive power, and both are necessary for performing motor functions. These details cannot be provided by isometric measurement which makes the FSM a better assessment of strength. Our finding of relative high correlations between reaching distance in the Y-balance and the explosive power items of the FSM also justifies this recommendation.

6.7.5 We recommend the Y-Balance test as an assessment of balance not just because it is dynamic but also because it does not have a ceiling effect like the one leg stance. In addition, since injury is more likely to take place in dynamic condition, the Y-Balance test can be used to identify individuals at risk of injury.

6.7.6 We recommend that children maximize physical education periods by engaging in physical activities such as walking, cycling, dancing, skipping, jogging, running and ball games [102].

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Appendix

Appendix 1: Letter of permission to the Local Government Education Authority-Uyo

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences

Department of Health and Rehabilitation Sciences

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Midwifery, Occupational Therapy, Physiotherapy; and Disability Studies
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Tel: +27 (0) 21 406 6628/ 6428/ 6534
Fax: +27 (0) 21 406 6323
www.dhrs.uct.ac.za

The Secretary,
Local Government Education Authority-Uyo
Akwa Ibom
28/12/2020

Dear Sir,

Letter of permission to conduct a research among primary school pupils in Uyo local government

I write to obtain permission to conduct a study among school-aged children in Uyo Local Government. I am a post-graduate student in the Division of Physiotherapy, University of Cape Town. As part of the requirements to obtain my PhD degree, I will be undertaking a study titled: **A longitudinal study on possible correlates that might explain the onset and progression of musculoskeletal symptoms in school-aged children with Generalized Joint Hypermobility.**

Joint Hypermobility (JH) is a state whereby an individual is able to move his/her joint more than the normal range of motion. Individuals with this ability are in large numbers among Nigerian children. JH is not a disorder until the child develops musculoskeletal complaints that affect their

physical fitness and participation levels. Even though the musculoskeletal complaints are not life threatening, they lead to secondary psychosocial complications, which have far reached effects on the child's quality of life.

Over the years, a number of cross-sectional studies have investigated children with symptomatic JH, but it is still not clear why and when these children develop symptoms. It is for this reason we wish to carry out a study on children with JH and assess them over a period to be able to identify when they develop symptoms and factors responsible for the development of symptoms.

The Human Research Ethics Committees of the University of Cape Town and University of Uyo Teaching Hospital will give ethics approval for the study. The study will require four schools in Uyo local government and all pupils in primaries 1-5 will be eligible to participate in the study. We will obtain permission from the Head teachers of the selected schools.

Informed consent

The pupil's guardian/parent will determine his/her participation in the study. The child will also give an assent on the day the assessment will be carried out. The child is free to decline participation and he /she can withdraw from the study at any time without any consequence on the child.

Assessments

The tests will be carried out in a safe and comfortable place in the school. I will conduct the tests with trained research assistants. The tests are simple with minimal risks and not time consuming. I will arrange with the schools so that the assessments can be carried out during physical education sessions, lunch break or after school hours. This is to ensure that the study does not affect their class work.

The children whose parents have given positive consent will be asked to perform activities to determine their motor coordination, proprioception, strength and balance levels. In addition, the parents and children will be required to fill questionnaires to obtain information on pain, physical activity level and quality of life.

Possible risks

Some of the assessments are physical test like running and hopping. This can make the children tired during or after the test. The children will be allowed to rest when they are tired and will be provided with water when they demand for it. We will also have a first aid kit with us when they perform the tests. I and the other research assistants will always be present when the children carry out the tests.

Benefits

We will send reports on the children's performances to the guardian/parent through written notes. We will advise the parents of children with motor impairments on how to support the children. We will give referral where necessary. We will advise the teachers on how to support the children with motor impairments, which will lead to better learning process in the class.

If you would like more information, please contact me, Oluwakemi Ituen tel. +2347031181086 Email itnolu001@uct.ac.za

If you would like to speak to someone from the Physiotherapy department, UCT, you may contact my supervisors;

Associate Prof Gillian Ferguson gillian.ferguson@uct.ac.za,

Prof. Bouwien Engelsman bouwiensmits@hotmail.com,

Dr Christie Akwaowo christie.d.akwaowo@gmail.com.

You may also call the Human Research Ethics Committee UCT for enquires. G50 Old Main Buil ding Groote Schuur Hospital, Observatory, 7925, hrec-enquiries@uct.ac.za, 021 650 1236

Yours faithfully

Ituen Oluwakemi

Appendix 2: Letter of permission to the Head Teacher

UNIVERSITY OF CAPE TOWN
Faculty of Health Sciences
Department of Health and Rehabilitation Sciences

Divisions of Communication Sciences and Disorders, Nursing and
Midwifery, Occupational Therapy, Physiotherapy; and Disability Studies
F45 Old Main Building, Groote Schuur Hospital
Observatory, Cape Town, W Cape, 7925
Tel: +27 (0) 21 406 6628/ 6428/ 6534
Fax: +27 (0) 21 406 6323
www.dhrs.uct.ac.za

The Head teacher,
Four Towns Primary School,
Abak road, Uyo,
Akwa Ibom state
28/12/2020

Dear Head Teacher,

Letter of permission to conduct a research among pupils aged 6-11 years in your school

I write to seek your permission to conduct a study among pupils aged 6-11 years in your school. I am a post-graduate student in the Division of Physiotherapy, University of Cape Town. As part of the requirements to obtain my PhD degree, I will be undertaking a study titled: **A longitudinal study on possible correlates that might explain the onset and progression of musculoskeletal symptoms in school-aged children with Generalized Joint Hypermobility.**

Joint Hypermobility is a state whereby an individual is able to move his/her joint more than the normal range of motion. A large number of Nigerian children have this ability. Joint hypermobility is not a disorder and some of them do well in sports. However, some children with joint hypermobility develop musculoskeletal complaints that affect their physical fitness and participation levels. Even though the musculoskeletal complaints are not life threatening, they lead to secondary psychosocial complications that have far reached effects on the child's quality of life.

Over the years, some researchers have tested children with symptomatic joint hypermobility, but have not been able to identify why and when these children develop symptoms. It is for this reason we wish to carry out a study on children with Joint Hypermobility and assess them yearly for a period of three years to identify when they develop symptoms and factors responsible for the development of symptoms. The research team will assess the children during the physical education sessions, break time or after school hours, so that it will not interrupt the children's learning period in the school.

Informed consent

The parent/guardian will determine the participation of the children in the study. The child will give an assent on the day of the assessments. The child is free to decline participation and he /she can withdraw from the study at any time without any consequence on the child.

What do I want you as the Headteacher to do?

I am asking for your permission to work with the children and provide a safe and comfortable venue in the school compound where the tests can be carried out.

What are the risks involved?

The inclusion of the school in the study does not carry any risk.

What are the benefits of participating?

The teachers will receive advice from the primary researcher on how to provide support and help the children who have poor motor performance. This will make the learning process in the class easier.

What about confidentiality and privacy?

The report of the study will not reveal the name of the school. The primary researcher will give a code to all the study participants. All the information from the parents and the children will be stored under a password-controlled access. All the information about the children will be confidential. However, as researchers we may not be able to maintain as confidentiality information about known or reasonably suspected indents of deliberate neglect or physical, sexual or emotional abuse of a child. If we are given such information, we may report it to relevant authorities such as child welfare and police.

Will I be paid for granting permission?

I am not offering money to the school however, water/snacks will be provided for the children during the tests.

If you would need more information, please contact me. Oluwakemi Ituen +2347031181086 Email itnolu001@uct.ac.za

If you would like to speak to someone from the UCT physiotherapy department, you may contact my supervisors;

Associate Prof Gillian Ferguson gillian.ferguson@uct.ac.za,

Prof. Bouwien Engelsman bouwiensmits@hotmail.com,

Dr Christie Akwaowo christie.d.akwaowo@gmail.com.

You may also call the Human Research Ethics Committee UCT for enquires. G50 Old Main Buil ding Groote Schuur Hospital, Observatory, 7925, hrec-enquiries@uct.ac.za, 021 650 1236

Yours faithfully

Ituen Oluwakemi

Appendix 3: Parents information and consent form

UNIVERSITY OF CAPE TOWN

Faculty of Health Sciences

Department of Health and Rehabilitation Sciences

Divisions of Communication Sciences and Disorders, Nursing and

Occupational Therapy, Physiotherapy; and Disability Studies

F45 Old Main Building, Groote Schuur Hospital

Observatory, Cape Town, Western Cape, 7925

Tel: +27 (0) 21 406 6628/ 6428/ 6534
Fax: +27 (0) 21 406 6323

www.dhrs.uct.ac.za

28/12/2020

Dear Parent/Guardian,

I write to seek your consent for the participation of your ward in a study that we will be carrying out in their school. I am a post-graduate student in the Division of Physiotherapy, University of Cape Town. As part of the requirements to obtain my PhD degree, I will be undertaking a study titled: **A longitudinal study on possible correlates that might explain the onset and progression of musculoskeletal symptoms in school-aged children with Generalized Joint Hypermobility.**

Joint Hypermobility is a state whereby an individual is able to move his/her joint more than the normal range of motion. A large number of Nigerian children have this ability. Joint hypermobility is not a disorder and some of them do well in sports. However, some children with joint hypermobility develop musculoskeletal complaints that affect their physical fitness and participation levels. Even though the musculoskeletal complaints are not life threatening, they lead to secondary psychosocial complications that have far reached effects on the child's quality of life.

Over the years, some researchers have tested children with symptomatic joint hypermobility, but have not been able to identify why and when these children develop symptoms. **It is for this reason we wish to carry out a study on children with Joint Hypermobility and assess them**

yearly for a period of three years to identify when they develop symptoms and factors responsible for the development of symptoms.

What am I asking you as parent/guardian to do?

I am seeking your consent to check how well your child performs his/her motor activities. If you need further clarifications on the study before you give your consent, you may either call me or meet me after school hours. If you agree, would you kindly sign the declaration form below and fill the bio-data attached. The first part of the questionnaire is about you and the second part is about your ward. I am asking these questions to know more about you and your child.

Please note your child will not be able to participate in the study if he/she has:

1. A body temperature of over 38^0C/ flu-like symptoms on the day of assessment.
2. An acute musculoskeletal injury 2-3 days prior to assessment.
3. A confirmed diagnoses of Ehlers Danlos Syndrome (EDS) as identified by a physician
4. A diagnosed developmental disability such as cerebral palsy known to affect motor coordination as identified by a parent or teacher.

The research team will screen all children before taking them for assessments.

What does your child have to do?

Your child will be tested once every year for the next three years. In addition, you be required to fill questionnaires on your ward's level of pain quarterly, physical activity level and quality of life biannually. A few examples: we will ask your child to throw and catch a ball, to stand and hop on one leg, to run, to write and balance on a beam. The tests will take 20-30 minutes. The joints of the elbows, knees and 5^{th} finger will also be measured after which he/she will perform some simple tasks with wedges and perform some balance test, which will last for another 20 minutes. In addition, your ward will be required to fill questionnaires on his/her level of pain quarterly, physical activity level and quality of life biannually. The questionnaires can be filled at home and returned to the primary researcher on a later date. We do not wish to interrupt your child's learning in school. Therefore, we will negotiate with the teachers to perform the tests during physical education sessions, break times or after school. If your child chooses to participate, he/she will sign a form to show that he/she has agreed. Your child may also stop the test whenever he/she wishes: it is all up to him/her.

What are the risks involved and what will ensure their safety?

The testing does not constitute more than a minimal risk which is the probability and magnitude of harm or discomfort anticipated in the research are not greater than those ordinarily encountered in daily life or during the performance of routine physical and psychological

examinations or tests and that confidentiality is adequately protected. If your child with needs further assessment, we will provide referred to appropriate medical practitioner in the University of Uyo Teaching Hospital. To prevent injuries because of fatigue, we will allow your child to rest when he/she gets tired. The researcher or a research assistant will be present during all tests and a first-aid kit will be kept on hand which will be administered should the need arise. In addition, we will provide water for your child. To avoid joint discomfort, trained physiotherapists will do goniometric tests. We will terminate the test if your child complains of joint pain at any stage.

What are the benefits of participating?

You will receive written reports of your child's performances on all the tests. If the motor performance is poor, we will advise you on how best to support him/her. If you will like to seek the services and support of other professional, we will provide you with a referral letter.

What happens if I do not want my child to take part in the study?

Your child's participation depends entirely on your consent. Your consent is voluntary. There will be no consequence if you withdraw your child from the study. Refusal to take part in this study will not affect the quality of education your child will receive. If you agree and then you change your mind and you no longer want them to take part, they can withdraw at any stage with no consequence.

What about confidentiality and privacy?

Both the information you provide through the questionnaire and child's results from all the tests will be stored under a password-controlled access. All the information I will gather about you and your child will be confidential. To maintain confidentiality in the study, we will not mention your name and that of your child when reporting the results of the study.

As a researcher, I may not be able to maintain as confidential, information about known or reasonably suspected incidents of deliberate neglect or physical, sexual or emotional abuse of a child. I will report such information to relevant authorities such as child welfare

Will my child and I be paid money for taking part in the study?

I am not offering any money to the parents or the children for taking part in this research study. H owever, each year all the children who take part in the study will receive biscuits/pen at the end o f the tests.

UCT No-Fault Insurance Policy:

If your child experiences a deterioration in his/her health or well-being due to unforeseen sensitiv ity related to participation in the study, medical care will be provided immediately by the univers ity of Cape Town. According to the Association of the British Pharmaceutical Industry 1991, UC T will compensate without having to prove it is the university's fault. A trial-related injury is defi ned as one caused by activities related to our study. If an injury or abnormal side-effects does occ ur, the researcher must be notified immediately.

UCT reserves the right to not provide compensation for participants who become injured as a result of not following the instructions given to them whilst taking part in the study however you still have the right to lawfully claim compensation for any injuries where you prove negligence was not the cause of the injury.

If you would like further information, please contact me.
You can visit me at your child's school. I will be there from date:……
Time: 1pm-2:30pm. Telephone +2347031181086. Email itnolu001@myuct.ac.za
If you would like to speak to someone from the UCT physiotherapy department, you may contact my supervisors;
Associate Prof Gillian Ferguson gillian.ferguson@uct.ac.za,
Prof. Bouwien Engelsman bouwiensmits@hotmail.com,
Dr Christie Akwaowo christie.d.akwaowo@gmail.com.
You may also call the Human Research Ethics Committee UCT for enquires. G50 Old Main Buil ding Groote Schuur Hospital, Observatory, 7925 hrec-enquiries@uct.ac.za, 021 650 1236

Yours faithfully

Ituen Oluwakemi

Appendix 4: Child's and parent's background information

Please answer all questions

All information given will be kept highly confidential.

Section A: About your child

1	Child's name	
2	Child's date of birth	
3	Child's school	
4	Child's class	
5	Does your child have any difficulty dressing up, writing and playing with friends?	Yes or No
	If yes describe:	

Has your child ever been diagnosed with any of the condition below?

1. Ehlers Danlos Syndrome by a doctor: Yes/No
2. Developmental disability by a doctor Yes/No
3. Cerebral Palsy Yes/no
4. Spinal Bifida Yes/No

Section B: About parent/guardian

1	Name	
2	Home address	
3	Telephone	
4	Email address	
5	Highest level of education	
6	Occupation	
7	Marital status	

Appendix 5: Parent's declaration form

I …….. (First name and surname), the parent of ……. (First name and surname of child) in primary…….

I have read the attached letter and I understand what is required of my child and I. I do not feel that I am forced to have my child participate and I am doing so out of my own free will. I know that I can withdraw my child at any time I so wish. I understand that withdrawal will have no consequence on my child.

PLEASE INDICATE YOUR CHOICE BY TICKING THE BOX BELOW AND SIGN NEXT TO THE BOX.

YES, I AGREE to let the researcher assess my child ☐

Signature ……

NO, I DO NOT AGREE to let the researcher assess my child ☐

Signature ……..

Thank you

Kindly return the form to the researcher

Appendix 6: Child's assent form

Declaration

I understand that I am expected to show the researchers how I perform some activities and answer some questions. I understand that I may feel tired during the tests, I can stop at any time, and no one will be angry with me. I understand that the researcher will inform my parents how well I performed so that plans can be made to help me if necessary.

If you understand and **AGREE** to show us how to perform these activities, please write your name in the box below

If you understand and **DO NOT AGREE** to show us how to perform these activities, please write your name in the box below

Appendix 7: Protocol for Beighton score

In the Beighton scoring system, the universal goniometer will be used to measure the passive bilateral dorsiflexion of the fifth metacarpophalangeal joint, the passive bilateral hyperextension of the elbow and knee. The other tests are bilateral passive apposition of the thumb to the forearm and the forward flexion of the trunk with knees straight. The test will take approximately 5-7 minutes.

1. Passive dorsiflexion of the fifth metacarpophalangeal joint. Score is positive if ≥ 90° (Bilateral testing)

Test position	Motion tested	Positioning Goniometer	Anatomical landmarks	Method
Sit on chair at the short side of the table with arm in 80° abduction, elbow flexed 90°, forearm resting on table, forearm pronated.	Passive Dorsiflexion Digiti 5.	MCP 5.	Dorsal side Metacarpalia 5; in the length of Digiti 5.	Lateral method.

2. Passive hyperextension of the elbow. Score is positive if ≥ 10° (Bilateral testing)

Test position	Motion tested	Positioning Goniometer	Anatomical landmarks	Method
Sit on chair with shoulder 90° anteflexion, forearm supinated	Passive hyperextension of elbow.	Lateral epicondyl Humerus.	Humurus pointed at tub major humeri; Radius pointed at proc styloideus.	Lateral method.

5. Forward flexion of the trunk, with the knees straight. Score is positive if the hand palms rest easily on the floor.

Score: Positive

Score: Negative

Scoring

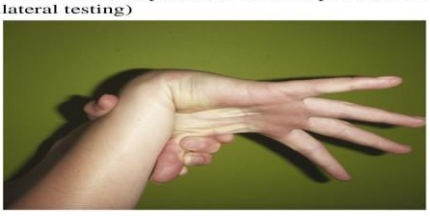
One point may be gained for each side for item 1-4 (max 2 per item if left and right are positive) and only one point in total for item 5.

The maximum hypermobility score is nine points (if all items are positive).

3. Passive hyperextension of the knee. Score is positive if ≥ 10° (Bilateral testing)

Test position	Motion tested	Positioning Goniometer	Anatomical landmarks	Method
Lying backwards with legs in horizontal position.	Passive hyperextension knee.	Lateral femur epicondyl.	Femur pointed at trochanter major; Fibula pointed at lateral malleolus.	Lateral method.

4. Passive apposition of the thumb to the flexor side of the forearm, while shoulder is 90° flexed, elbow extended and hand pronated. Score is positive if the whole thumb touches the flexor side of the forearm. (Bilateral testing)



Score: Positive

Score: Negative

Score sheet for Beighton score

Table 8-1: Score Sheet for Goniometric assessment

Description Testing	Bilateral	Scoring[max. point]
Passive dorsiflexion of the 5th metacarpophalangeal joint to ≥ 90 degrees	Yes	2
Passive hyperextension of the elbow ≥ 10 degrees	Yes	2
Passive hyperextension of the knee ≥ 10 degrees	Yes	2
Passive apposition of the thumb to the flexor side of the forearm , while the shoulder is flexed at 90 degrees , elbow is extended and hand is pronated	Yes	2
Forward flexion of the trunk, with the knees straight, so that the hand palms rest easily on the floor.	No	1
Total		9

Table 8-2: Diagnosis of HSD

S/no	Musculoskeletal symptoms	Present/absent
1	Trauma (subluxation, dislocation, sprain) • Location of injury • Cause of injury • Time of injury	
2	Chronic pain • Location of pain • Duration of pain • Is pain related to activity? • Does pain occur in the night? • What relieves the pain?	
3	Flat feet/scoliosis	
4	Impaired proprioception/muscle weakness	
5	Osteoarthritis	
6	Poor motor coordination	

Beighton score =
Number of musculoskeletal symptoms =
Diagnosis of HSD

Appendix 8: Shuttle run test

The materials needed for the shuttle run test are marker cones, measurement tape, stopwatch, and a non-slip surface. Participants run 20 meter back and forth keeping time track. The athlete's score is the level and number of laps (20m) reached before they were unable to keep up with the recording.

Score sheet for shuttle run test

Table with runs and levels

Name:_____

Classs: _____

Date: _____ ____

Time: _____ _____

Surface: _____

Conditions:_____

1.1	1.2	1.3	1.4	1.5	1.6	1.7									
2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8								
3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8								
4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9							
5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.9							
6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9	6.10						
7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	7.10						
8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	8.10	8.11					
9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	9.10	9.11					
10.1	10.2	10.3	10.4	10.5	10.6	10.7	10.8	10.9	10.10	10.11					
12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	12.10	12.11	12.12				
13.1	13.2	13.3	13.4	13.5	13.6	13.7	13.8	13.9	13.10	13.11	13.12	13.13			
14.1	14.2	14.3	14.4	14.5	14.6	14.7	14.8	14.9	14.10	14.11	14.12	14.13			
15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9	15.10	15.11	15.12	15.13			
16.1	16.2	16.3	16.4	16.5	16.6	16.7	16.8	16.9	16.10	16.11	16.12	16.13	16.14		
17.1	17.2	17.3	17.4	17.5	17.6	17.7	17.8	17.9	17.10	17.11	17.12	17.13	17.14		
18.1	18.2	18.3	18.4	18.5	18.6	18.7	18.8	18.9	18.10	18.11	18.12	18.13	18.14	18.15	
19.1	19.2	19.3	19.4	19.5	19.6	19.7	19.8	19.9	19.10	19.11	19.12	19.13	19.14	19.15	
20.1	20.2	20.3	20.4	20.5	20.6	20.7	20.8	20.9	20.10	20.11	20.12	20.14	20.15	20.16	
21.1	20.2	21.3	21.4	20.5	20.6	21.7	21.8	20.9	20.10	21.11	21.12	21.13	21.14	21.15	21.1

Appendix 9: Hand held dynamometer placement

The Hand held dynamometer (Lafayette Manual Muscle Testing System, Lafayette Instrument NY) measure isometric muscle strength.

Table 8-3: Subject and HHD Position

Muscle group	Subject position	Dynamometer position
Knee extensors	Sitting, knee at 90^0.	Anterior surface of the distant shunt just proximal to the heel.
Ankle dorsiflexors	Supine, foot at 90^0.	Proximal to the metatarsophalangeal joint.
Ankle plantarflexors	Supine, foot at 90^0.	On the ball of the foot.

HHD score form

Table 8-4: Score sheet for HHD

Muscles	Trial 1 (N)	Trial 2 (N)	Trial 3 (N)	Best score (N) (in data base)
Knee extension right				
Knee extension left				
Ankle Plantarflexion right				
Ankle Plantarflexion left				
Ankle Dorsi flexion right				
Ankle Dorsiflexion left				
Left grip strength				
Right grip strength				

Appendix 10: The Functional Strength Measurement

The Functional Strength Measurement measures the different component of muscular fitness (strength, endurance, power) giving it an advantage over other strength tests. It takes a minimum of 30 minutes to complete

Table 8-5: Items of the Functional Strength Measurement (FSM)

Item	Construct	Activity	Muscle Function	Coordination
Item 1. Overarm throwing Item 3. Underarm throwing.	Muscle power: ability to generate one explosive movement.	Children aged 4–10 years regularly play games that involve throwing and catching a ball.	There is a relationship between muscle power and distance covered.	Tests of motor proficiency, such as the Movement Assessment Battery for Children–2, include throwing activities, but performance is measured in terms of the accuracy of the throw (aiming) and not the throwing distance; for the FSM, the distance that an object could be thrown was assessed, and accuracy was not important.
Item 2. Standing long jump	Muscle power: ability to generate one explosive movement.	Children use jumping as a part of games.	There is a relationship between muscle power and distance covered.	Requires balance, planning, and coordination if a child also is required to jump within a defined space (e.g., square); spatial constraints were minimized by not defining a landing area or landing posture.

Item 4. Lateral step-up	Muscle endurance: number of repetitions within 30 s	Although the isolated movement lateral step-up is not functional, the action is similar to stepping up onto a bike or scooter and is somewhat similar to stepping on stairs or pavement.	This task provides a general impression of the endurance of the extensor muscles of the lower extremities, in particular, the quadriceps and hip abductor muscles.	This task has also been used in cerebral palsy and has low coordination requirements; children may place their fingers on a wall to lower balance requirements
Item 5. Chest pass	Muscle power: ability to generate one explosive movement.	The ball throw or pass makes use of a movement pattern used in many sports, such as basketball and volleyball.	Upper limb and trunk muscle power.	In this task, children sitting on the ground have to fixate their backs against a wall; movements are isolated to the upper limbs.
Item 6. Sit to stand	Muscle endurance: number of repetitions within 30s.	Standing up from a chair and sitting down is an activity children perform numerous times each day.	Hip and knee extensor muscles are important.	Requires some level of balance and coordination; the coordination level of this task was minimized by allowing standing on 2 legs and stretching the arms outward to encourage weight transfer; this task also was used in cerebral palsy.

Item 7. Lifting a box	Muscle endurance: number of repetitions within 30s.	Children aged 4–10 years regularly pick up heavy objects (e.g., a box of blocks) Stair	Upper limb and trunk muscle endurance.	Requires some coordination to control trunk stability while lifting and placing a box in a certain area, but this large area has no strict borders.
Item 8. Stair climbing	Muscle endurance: number of repetitions within 30s.	Stair climbing and climbing a play structure are skills involving alternating leg movements.	Lower limb muscle endurance; no arm support allowed.	Requires coordination to keep balance while briefly standing on one leg and accuracy to place foot on a wide step.

Appendix 11: Y-Balance test

The Y-Balance is a dynamic test whereby one maintains single-leg stance balance while reaching as far as possible with the contralateral leg in the anterior, posteromedial and posterolateral directions. It takes approximately 7-10 minutes to perform the test.

Performance of the Y-balance task using the right leg as the stance limb in the,

a, anterior,

b, posterolateral, and

c, posteromedial direction

Score sheet for Y-Balance

Name: Participant number:
Age:
Class:
Date:

Standing on Right leg	1st trial	2nd trial	3rd trial
Anterior			
Posterolateral			
Posteromedial			
Standing on Left leg	1st trial	2nd trial	3rd trial
Anterior			
Posterolateral			
Posteromedial			

Appendix 12: Faces Pain Scale

To administer the Faces Pain Scale, participants will be asked to choose the face that best reflects the intensity of the pain they have experienced.

Figure 8-1: Faces Pain Scale

Score sheet for FPS:

Name:
Age:
Class:
Date:
Pain score:

Appendix 13: Physical Activity Questionnaire

The physical activity questionnaire is a recall of activities in the last seven days. It is feasible for large-scale studies as it is cost/time efficient.

We are trying to find out about your level of physical activity from ***the last 7 days*** (in the last week). These includes sports or dance that make you sweat or make your legs feel tired, or games that make you breathe hard, like tag, skipping, running, climbing, and others.

Remember:

1. There are no right and wrong answers — this is not a test.
2. Please answer all the questions as honestly and accurately as you can — this is very important.

1. Physical activity in your spare time: Have you done any of the following activities in the past 7 days (last week)? If yes, how many times? (Mark only one circle per row)

	No	1-2	3-4	5-6	7 times or more
Arm wrestling……					
Hide and seek…….					
Hop scotch ……..					
Skipping					
Walking for exercise					
Cycling					
Jogging or running					
Swimming					
Dancing					
Volley ball…….					
Football					
Basketball					
Table soccer…….					
Table tennis……..					

Others:

2. In the last 7 days, during your physical education (PE) classes, how often were you very active (playing hard, running, jumping, throwing)? (Check one only.)

I don't do PE .....…...
Hardly ever .....
Sometimes .....
Quite often .....
Always .....

3. In the last 7 days, what did you do most of the time *at recess*? (Check one only.)

Sat down (talking, reading, doing schoolwork)……..
Stood around or walked around .....
Ran or played a little bit .....
Ran around and played quite a bit .....
Ran and played hard most of the time .....

4. In the last 7 days, what did you normally do *at lunch* (besides eating lunch)? (Check one only.)

Sat down (talking, reading, doing schoolwork)…...
Stood around or walked around .....
Ran or played a little bit .....
Ran around and played quite a bit .....
Ran and played hard most of the time .....

5. In the last 7 days, on how many days *right after school*, did you do sports, dance, or play games in which you were very active? (Check one only.)

None .....…
1 time last week .....
2 or 3 times last week .....
4 times last week .....
5 times last week .....

6. In the last 7 days, on how many *evenings* did you do sports, dance, or play games in which you were very active? (Check one only.)

None .....
1 time last week .....
2 or 3 times last week .....
4 or 5 last week .....
6 or 7 times last week .....

7. *On the last weekend*, how many times did you do sports, dance, or play games in which you were very active? (Check one only.)

None .....
1 time last week .....
2 or 3 times last week .....
4 or 5 last week .....
6 or 7 times last week .....

8. Which *one* of the following describes you best for the last 7 days? Read *all five* statements before deciding on the *one* answer that describes you.

A. All or most of my free time was spent doing things that involve little physical effort.....
B. I sometimes (1 — 2 times last week) did physical things in my free time (e.g. played sports, went running, swimming, bike riding, did aerobics) .....……
C. I often (3 — 4 times last week) did physical things in my free time .....……..
D. I quite often (5 — 6 times last week) did physical things in my free time ……...
E. I very often (7 or more times last week) did physical things in my free time …….

9. Mark how often you did physical activity (like playing sports, games, doing dance, or any other physical activity) for each day last week.

	None	Little bit	Medium	Often	Very often
Monday……..					
Tuesday…….					
Wednesday……					
Thursday…….					
Friday……..					
Saturday……..					
Sunday ……					

10. Were you sick last week, or did anything prevent you from doing your normal physical activities? (Check one.)

Yes .....……□□

No ..... □□

If Yes, what prevented you? _____

Appendix 14: Child Activity Limitation Interview (questionnaire version)

In the Child Activity Limitation Interview (questionnaire version) the respondents (child/parent) recall the activities of the previous four weeks and rates how difficult it was performing them due to pain. The questionnaire has 21 items and a high score indicates greater activity limitations or impairment.

CALI-21 Child report

Think about your activities over the last four weeks. Please rate how difficult or bothersome doing these activities was for you because of pain.

	Not very difficult	A little difficult	Somewhat difficult	Very difficult	extremely difficult
1. Going to school	0	1	2	3	4
2. Gym	0	1	2	3	4
3. Reading	0	1	2	3	4
4. Schoolwork	0	1	2	3	4
5. Sports	0	1	2	3	4
6. Doing a hobby	0	1	2	3	4
7. Playing with friends	0	1	2	3	4
8. Watching TV	0	1	2	3	4
9. Housework or chores	0	1	2	3	4
10. Working at a job	0	1	2	3	4
11. After school practices	0	1	2	3	4
12. Doing things with friends	0	1	2	3	4
13. Going to clubs/church activities	0	1	2	3	4
14. Running	0	1	2	3	4
15. Walking up stairs	0	1	2	3	4
16. Eating regular meals	0	1	2	3	4
17. Riding in the school bus or car	0	1	2	3	4
18. Walking one or two blocks	0	1	2	3	4
19. Sleep	0	1	2	3	4
20. Riding a bike or scooter	0	1	2	3	4
21. Being up all day (without a nap or rest)	0	1	2	3	4

CALI-2: Parent Report

Think about your child's activities over the last four weeks. Please rate how difficult or bothersome doing these activities was for your child because of **pain.**

	Not very difficult	A little difficult	Somewhat difficult	Very difficult	extremely difficult
1. Going to school	0	1	2	3	4
2. Gym	0	1	2	3	4
3. Reading	0	1	2	3	4
4. Schoolwork	0	1	2	3	4
5. Sports	0	1	2	3	4
6. Doing a hobby	0	1	2	3	4
7. Playing with friends	0	1	2	3	4
8. Watching TV	0	1	2	3	4
9. Housework or chores	0	1	2	3	4
10. Working at a job	0	1	2	3	4
11. After school practices	0	1	2	3	4
12. Doing things with friends	0	1	2	3	4
13. Going to clubs/church activities	0	1	2	3	4
14. Running	0	1	2	3	4
15. Walking up stairs	0	1	2	3	4
16. Eating regular meals	0	1	2	3	4
17. Riding in the school bus or car	0	1	2	3	4
18. Walking one or two blocks	0	1	2	3	4
19. Sleep	0	1	2	3	4
20. Riding a bike or scooter	0	1	2	3	4
21. Being up all day (without a nap or rest)	0	1	2	3	4

Appendix 15: Pediatric Quality of Life Inventory

Pediatric Quality of Life Inventory (PedsQL) has four domains and there are three self-reported children's versions for age groups 5 to 7 years, 8 to 12 years, and 13 to 18 years and separate parent proxy reports for age groups 2 to 4 years, 5 to 7 years, 8 to 12 years, and 13 to 18 years. It takes approximately 5 minutes to complete. There are translations of PedsQL in other languages but none in any of the Nigerian dialects. Our study will be among English speaking children and parents, so we will use the children and parents English version of PedsQL 4.0.

The Child and Parent Reports of the **PedsQLTM** 4.0 Generic Core Scales for:

- Young Children (ages 5-7),

- Children (ages 8-12), are composed of 23 items comprising 4 dimensions.

Appendix 16: Wedges

We tested proprioception using the wedges (heel-height difference). The wedges are of various heights that produce different angles equal in surface (anti-slip layer) and length (see figure 5 and 6). Wedges of the following angles will be used 1.5°, 3°, 4.5^0 , 6°, 9° and 12° angle of to be able to detect smaller differences in the outcomes.

Figure 8-2: Wedges with different height

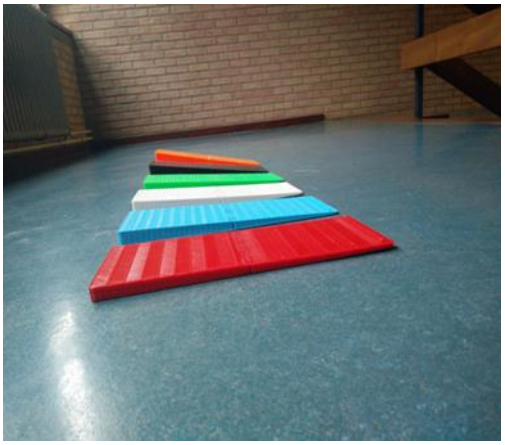


Figure 8-3: Wedges of different heights

Before the commencement of the test, we checked for discrepancy by measuring the leg lengths. The participant lay down in the supine position for the measurement of the leg lengths. Next, the participant were instructed to stand behind a table, which can use for support if needed. So that the balance of the study participants are not affected, they were not fully blinded during the testing.

While standing on the wedges, (without support from the table) they raised the arm of the side with the higher ankle. For example, the right arm for the right ankle. Both arms will be raised when no difference in ankle-height. The subject had 5 seconds to respond. The penalty score will depend on the height of the wedges. The higher the wedges height difference, the higher the penalty score. A high penalty score indicates poor proprioception. A penalty score will be awarded to every incorrect response. Inability to detect the highest wedge difference will get the highest penalty score. The individual penalty scores will be summed up to get a total penalty; a high penalty score will indicate poor proprioception.

Score sheet for the Wedges test

Name: I.D. No: Sex: Tester

Set 1	**Right**	**Left**	**answer**	**Response 1=correct 0=incorrect**
1	9^0	12^0	Left	
2	12^0	3^0	Right	
3	1.5^0	3^0	Left	
4	6^0	1.5^0	Right	
5	9^0	6^0	Left	
6	9^0	9^0	catch	
7	4.5^0	9^0	left	
Set 2	**Right**	**Left**	**answer**	**Response 1=correct 0=incorrect**
1	3^0	3^0	Catch	
2	12^0	3^0	Right	
3	6^0	12^0	Left	
4	4.5^0	6^0	Left	
5	9^0	4.5^0	Right	
6	6^0	9^0	Left	
7	1.5^0	6^0	Left	
Set 3	**Right**	**Left**	**answer**	**Response 1=correct 0=incorrect**
1	4.5^0	3^0	Right	
2	6^0	4.5^0	Right	
3	3^0	6^0	Left	
4	9^0	3^0	Right	
5	9^0	9^0	Catch	
6	3^0	9^0	Left	
7	9^0	3^0	Right	

Appendix 17: Joint position reproduction test

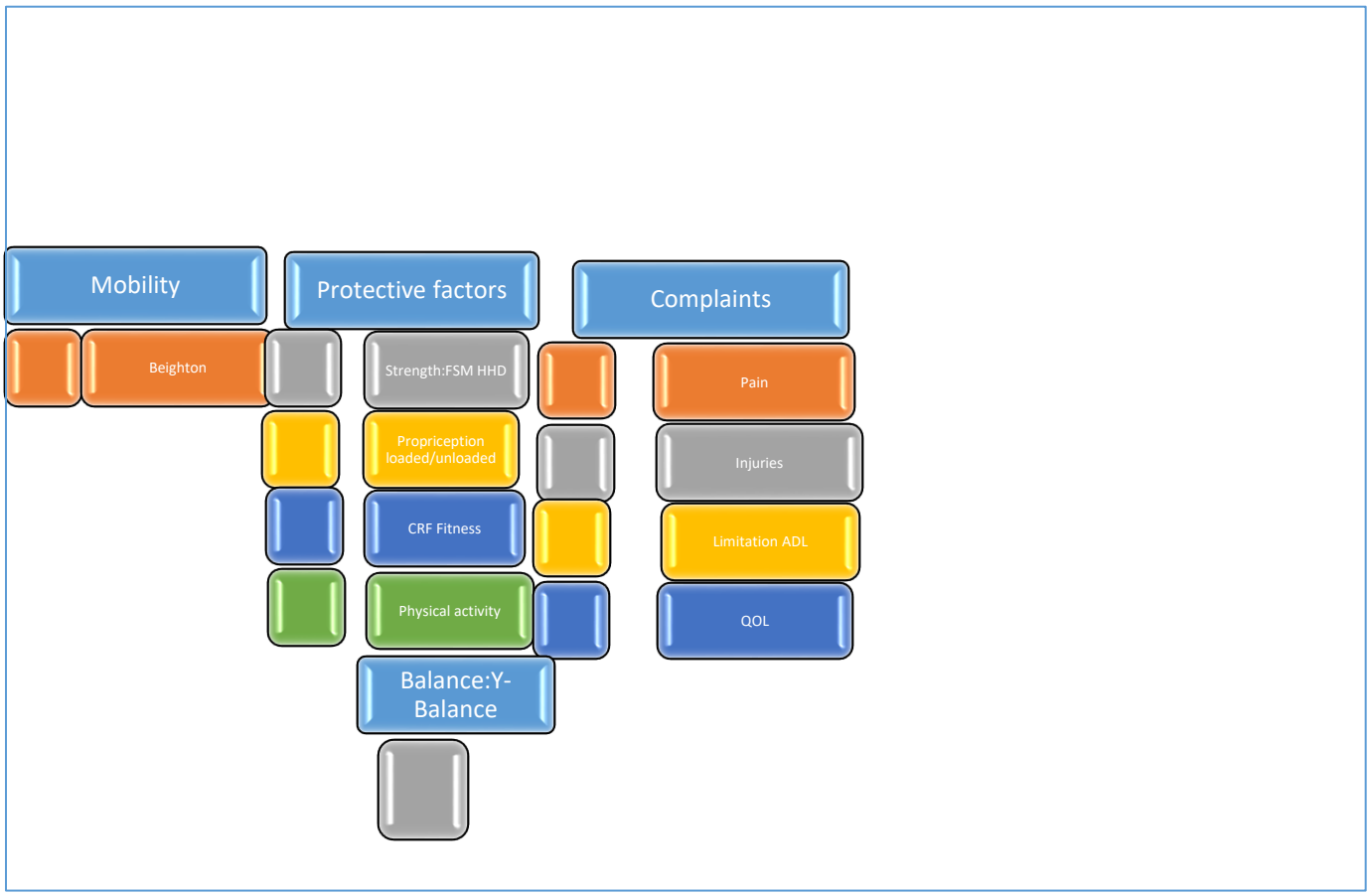
Bilateral joint position reproduction result sheet

S/No	Position (bilateral)	Test angle	Matching angle	difference
1	PA vs NPA	50		
2	PA vs NPA	70		
3	PA vs NPA	90		
4	PA vs NPA	110		
5	NPA vs PA	70		
6	NPA vs PA	90		
7	NPA vs PA	110		
8	NPA vs PA	50		

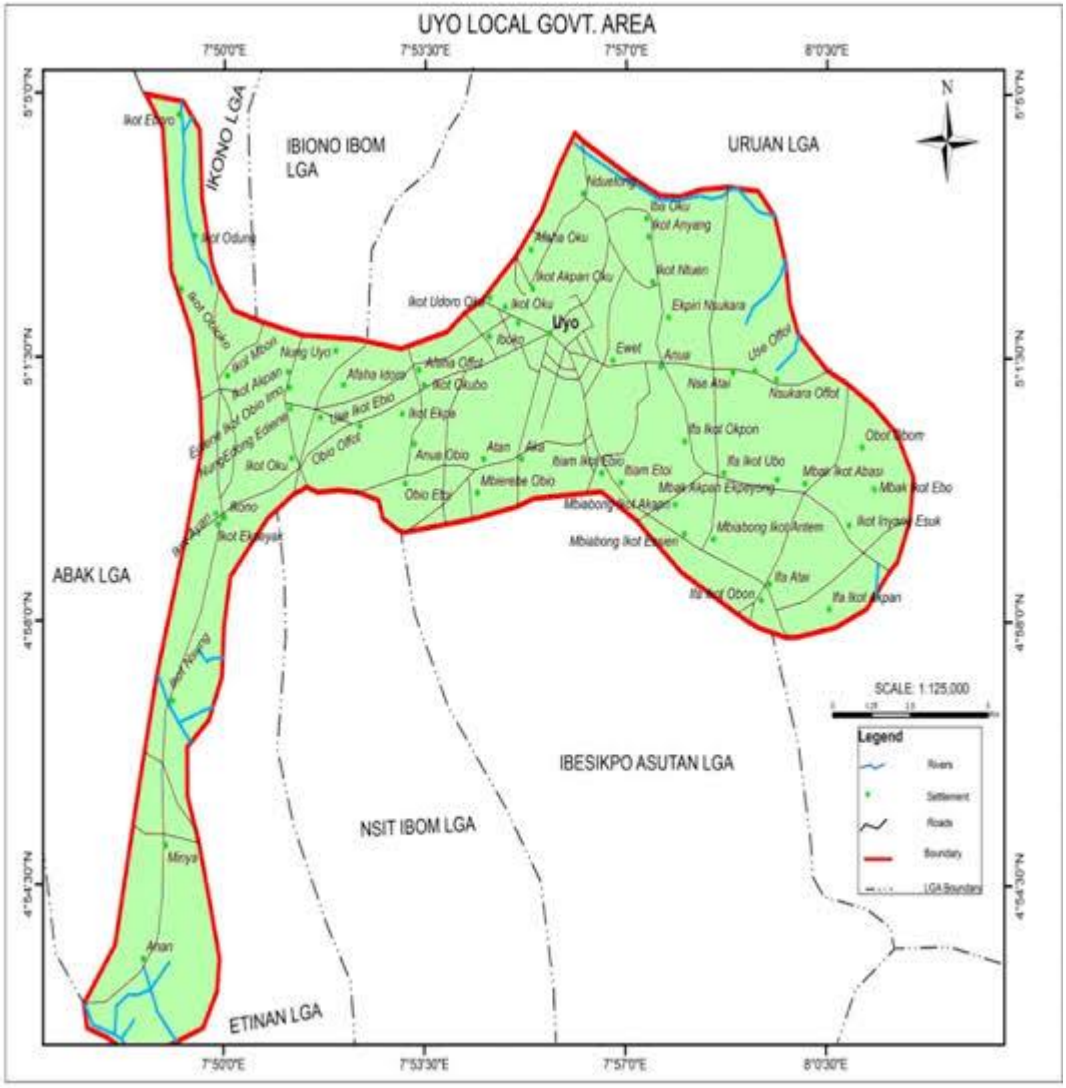
Unilateral joint position reproduction result sheet

S/No	Position (unilateral)	Test angle	Matching angle	difference
1	PA	50		
2	PA	70		
3	PA	90		
4	PA	110		
5	NPA	70		
6	NPA	90		
7	NPA	110		
8	NPA	50		

Appendix 18: Outline of tests, instruments /outcomes



Appendix 19: Map of Uyo Local Government Area, Akwa Ibom State



Appendix 20: Authors' contribution

Paper 1

Study conception and design: BSE, OAI, GF, JD. Acquisition of data: OAI, EMA. Analysis and interpretation of data: BSE, OAI, EMA. Project supervision: BSE & GF. Writing and editing of manuscript: BSE, OAI, EMA, GF, JD. All authors read, revised, and approved the final version of manuscript.

Paper 2

Study conception and design: BSE, OAI, GF, JD. Acquisition of data: OAI, BSE. Analysis and interpretation of data: BSE, OAI. Project supervision: BSE and GF. Writing and editing of manuscript: OAI, BSE, JD, GF. All authors read, revised, and approved the final version of manuscript.

Paper 3

Study conception and design: BSE, OAI, GF, JD. Acquisition of data: OAI, BSE. Analysis and interpretation of data: BSE. Project supervision: GF, BSE. Writing and editing of manuscript: OAI, BSE, JD, GF. All authors read, revised, and approved the final version of manuscript.

Paper 4

Study conception and design: BSE, OAI, and GF. Acquisition of data: OAI, BSE CDA. Analysis and interpretation of data: BSE, OAI. Project supervision: BSE & GF. Writing and editing of the manuscript: OAI, BSE, CDA, GF, JD. All the authors have read, revised, and approved the final version of the manuscript.