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Specificity of manual testing of the gluteal muscle strength in preschool children: a single-center cross-sectional study

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Abstract

Background: Manual Muscle Testing (MMT) is a procedure used to assess the strength and function of individual muscles and muscle groups based on effective movement in relation to the forces of gravity and manual resistance. The introduction of MMT into the diagnosis of developmental age is a complex issue due to the challenge of obtaining cooperation from the child undergoing the test. While some authors have attempted to implement MMT in children, clear recommendations regarding the lower age limit have not been firmly established.

Aims: This study aimed to establish the criteria for conducting MMT in healthy preschool children, identify standard protocols for test administration, and assess the potential influence of biometric parameters (such as age, gender, height, and weight) on test performance.

Material and methods: A group of 111 children underwent observation and was divided into two age groups. Group I comprised children aged from the completion of the 3rd year to the beginning of the 5th year (n=47; 24 girls, 23 boys; mean age 4.06±0.42 years, body weight 17.71±2.81 kg, and body height 104.9±6.50 cm). Group II included children aged from the completion of the 5th year to the beginning of the 7th year (n=54; 23 girls and 31 boys; mean age 5.79±0.60 years, body weight 21.6±3.68 kg, and body height 116.6 ±7.59 cm). The standard MMT position was utilized for assessment.

Key words

motor skills, gluteus maximus, preschool age, manual muscle testing, children.

Results: In the observed group, various methods of completing the test were identified (variants I, II, III, IV). Significant differences between groups (I and II) were observed only for variant II, both on the right (p=0.042) and left (p=0.012) sides of the body.

Conclusions: In the group of younger children, there is a preference for variants requiring the engagement of numerous muscle groups (variant IV), whereas in the older children's group, the predominant choice is a more isolated form of test performance (variant I). The selection of test variants is influenced by specific biometric parameters such as age, height, and weight. Gender was found to have no influence on the choice of variant.

Introduction

Manual Muscle Testing (MMT) is a procedure for assessing the strength and function of individual muscles and muscle groups based on effective movement in relation to gravity and manual resistance [1–3]. MMT is extensively described in the literature, particularly in relation to adults. Detecting dysfunction in specific muscles or muscle groups during the diagnostic process provides clear guidance for implementing targeted therapy.

Introducing MMT into developmental age diagnostics is a complex matter due to the lack of cooperation from the child undergoing the examination. Additionally, the dynamically changing motor and cognitive development of the child poses a challenge in establishing norms for specific tests used in adults. When conducting a comprehensive musculoskeletal diagnosis, it is crucial to establish norms initially to assess deviations in various clinical cases. Therefore, testing children with typical development is essential to identify reference values for the developmental stage of a specific function and/or determine the manner of response to a test task. Analyzing the identification of normative movement behaviors, it is important to emphasize that a characteristic of normal development is 'variability.' This entails the expression of a broad repertoire of behaviors for a specific motor function, meaning the ability to perform a task in several ways (richness of repertoire). This characteristic particularly applies to younger children (infancy, post-infancy period) but may also occur when introducing new, more complex movements in preschool children.

Evaluating muscle strength and function in the infancy and early post-infancy period (from birth to around two years old) involves observing global movement patterns such as rolling, sitting, standing, and walking. The acquisition of these skills indicates neuromuscular control efficiency and, consequently, the strength and function of individual muscles [4,5]. During preschool, children no longer acquire new patterns but refine previously acquired ones. This process is well exemplified by the variability in gait over time – the more extended walking persists, the more it resembles that of an adult [6]. The primary tool for assessing muscle strength and function during this period continues to be evaluating global movement patterns (motor skills – standing up, walking, running, standing on one leg, jumping). For instance, the ability to transition from a squat to a standing position suggests appropriate strength and function of lower limb muscles (quadriceps, glutes) [7]. The preschool period thus serves as a transitional phase between the developmental specificity observed in young children (acquiring new movement patterns) and the characteristics of older children's development (perfecting acquired movement patterns). These two overlapping developmental processes during the preschool period and varying cognitive development levels present fundamental challenges in neurodevelopmental diagnosis. Considering the above, a 'sharp' transition from a global assessment of movement patterns to manual muscle testing is not feasible.

Only a few authors have attempted to introduce MMT in children, but they have not established clear recommendations regarding the lower age limit. The only conclusions that have been adopted concern defining the age range between 5 and 10 years. Furthermore, the authors unanimously agree that a prerequisite for introducing testing is an adequate level of cognitive and language development that enables the execution of instructions [8,9].

Aims

The authors of this project attempted to verify the feasibility of introducing MMT in preschool-aged children (from the completion of the third year to the beginning of the seventh year). From the MMT battery, the position used to assess the strength of the gluteal muscles was selected [10], and the entire examination procedure was developed specifically for this project. The detailed objectives of the study included standardizing conditions for conducting manual testing in healthy preschool children, identifying typical ways of performing the test, and determining whether biometric parameters (age, gender, height, and body weight) could influence the execution of the test task.

Material and methods

Study group

One hundred and one children met the selection criteria and were included in the observational group. Inclusion criteria comprised an age range from 3 to 7 years, the ability to follow verbal commands, and typical, undisturbed neuromotor development. Exclusion criteria included obesity, a history, or current diagnoses of orthopedic or neurological conditions (e.g., fractures, congenital deformities, cerebral palsy, etc.). A group of 14 children were excluded (nine due to obesity and five for not following verbal commands). Children meeting the selection criteria were divided into two subgroups based on age. Group I included children from the completion of the 3rd year to the beginning of the 5th year (n=47; 24 girls, 23 boys; mean age 4.06±0.42 years, body weight 17.71±2.81 kg, and body height 104.9±6.50 cm). Group II included children from the completion of the 5th year to the beginning of the 7th year (n=54; 23 girls and 31 boys; mean age 5.79±0.60 years, body weight 21.6±3.68 kg, and body height 116.6±7.59 cm). Participants in the observation received detailed information about the objectives and procedures, and no cases of withdrawal from the study were recorded. Written informed consent from parents was obtained for all children included in the study. The study was approved by the institutional research ethics committee.

Research project

To verify the feasibility of introducing manual testing in preschool-aged children, the position used in MMT for testing the gluteal muscles was utilized [10]. However, the procedure and testing principles were explicitly developed for this project. The following measures were applied: 1) a position in the form of a platform serving as a reference point during the elevation of the lower limb, 2) proprioceptive instructions (performing the movement three times with the assistance of the examiner), and 3) verbal instructions tailored to the preschool-aged child's understanding level (Touch your foot to the ceiling). The height of the platform was individually adjusted for each child. It was established that each participant would cover the exact distance between the floor and the ceiling of the platform (15 cm). Additionally, manual resistance was not applied (the child's limb's weight was considered resistance), and no stabilization was used during the test (the child was taught to keep the pelvis on the surface during proprioceptive instructions). The aim of these measures was to assess whether the child could activate the gluteal muscles to lift the limb to a height of 15 cm.

Research procedure

The child, lying supine, followed proprioceptive and verbal instructions to carry out three independent trials, always starting from the right side. It was decided that the result from the third trial would be considered, acknowledging the growing comprehension of task execution over time. The entire test was captured by three cameras, with two positioned on the right and left sides of the subject and the third placed at the back. In these meticulously standardized conditions, a pilot study was conducted with a group of children matched in age to Group I (n=10) and Group II (n=12) to pinpoint variations in test performance. The researchers identified four ways of executing the test, hereafter denoted as Variants: I, II, III, IV (**Figs. 1-4**).

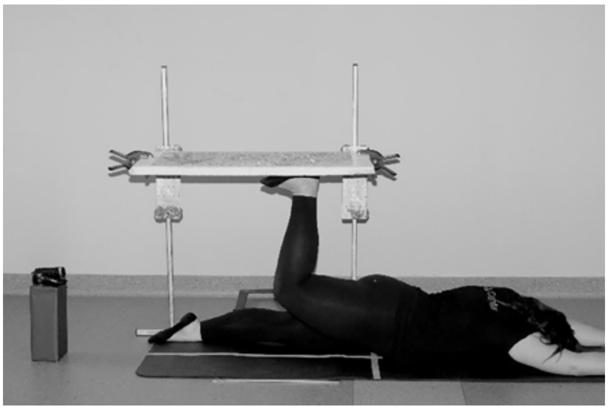

Figure 1. Variant I – lifting the thigh with the knee joint maintained at a right angle.

Figure 2. Variant II – lifting the thigh with an increased flexion at the knee joint.

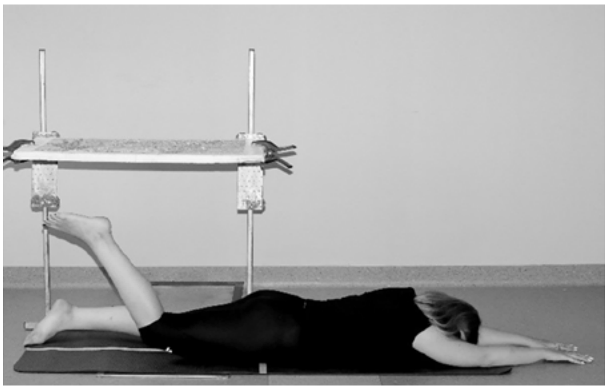

Figure 3. Variant III – lifting the thigh with increased extension at the knee joint.

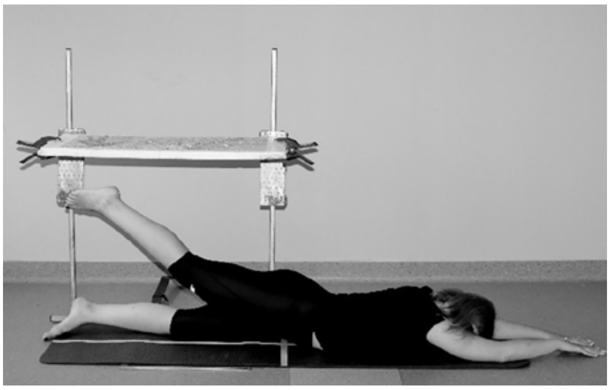

Figure 4. Variant IV – lifting the thigh along with the pelvic girdle.

Subsequently, the video material was sent to two independent assessors to categorize each method of test execution into Variant I, II, III, or IV.

Statistical analysis

Cohen's Kappa coefficient was utilized to assess the agreement between the two assessors categorized into Variants I, II, III, and IV [11]. Landis and Koch [12] used threshold values to estimate the level of agreement. Pearson chi-square test was employed to examine the relationship between a specific test variant and the side of the body. The structure indicator test was conducted to determine the percentage participation of a specific variant in the studied group. Discriminant analysis was chosen to assess the impact of biometric parameters on the selectivity of individual test variants (age, gender, body weight, and height). The critical level of significance was set at 0.05. Statistical analysis was performed using the STATISTICA 13.1 software (TIBICO, Palo Alto, USA).

Results

The results of the analysis of Cohen's Kappa coefficient agreement are presented in **Table 1**.

The obtained comparison values fell within the ranges from moderate to almost perfect, except for Variant IV in Group I, for the left side, which achieved a value below the level for random distribution in the contingency table.

Next, the relationship between the test variant and the side of the body in both groups was determined (**Table 2**).

A structure indicator test was conducted to verify the percentage participation of a specific variant in the general population. As a result of the analysis, significant differences were found be-

Table 1. Analysis of the Cohen's Kappa coefficient agreement in Groups I and II.

Group	Side of the body	Tested Variant			
		I	II	III	IV
I	Right	0.80	0.89	0.76	0.54
	Left	0.85	0.81	0.84	-0.06
II	Right	0.74	0.75	0.74	1.00
	Left	0.54	0.65	0.60	0.65

Legend: *0.00-0.20: Poor agreement; 0.21-0.40: Fair agreement; 0.41-0.60: Moderate agreement; 0.61-0.80: Substantial agreement; 0.81-1.00: Almost perfect agreement.*

Table 2. The relationship between the test variant and the side of the body in Groups I and II.

Group I Tested Variant	Right side [%]	Left side [%]	Group II Tested Variant	Right side [%]	Left side [%]
I	7.86 p = 0.005	34.08 p<0.001	**I**	44.00 p<0.001	40.59 p<0.001
II	37.92 p<0.001	31.71 p<0.001	**II**	22.45 p<0.001	27.50 p<0.001
III	25.41 p<0.001	34.72 p<0.001	**III**	55.00 p<0.001	13.63 p=0.002
IV	39.30 p=0.007	0.09 p<0.001	**IV**	16.59 p<0.001	35.97 p<0.001

Notes: *Chi^2 test.*

tween the two groups (I and II) only in the selectivity of Variant II on both the right and left sides (respectively: p=0.042; p=0.012). The remaining variants did not show significant differentiation.

Discriminant analysis was conducted to assess the impact of biometric parameters (age, gender, height, body weight) on the selectivity of individual test variants. The selection of Variant I on both the right and left sides was significantly influenced by body height (respectively: p=0.014; p=0.006), and additionally, on the right side, age (p=0.030) had a significant impact (**Fig. 5**). The results obtained for the right side of the body (**Figs. 5-7**) are illustrated below.

The selection of Variant II on both the right and left sides was significantly influenced by body height (respectively: p=0.011; p=0.006).

No significant impact of biometric parameters on the selection of Variant III was observed. However, the selection of Variant IV showed a significant influence of body weight on both the right and left sides (respectively: p=0.0004; p=0.001).

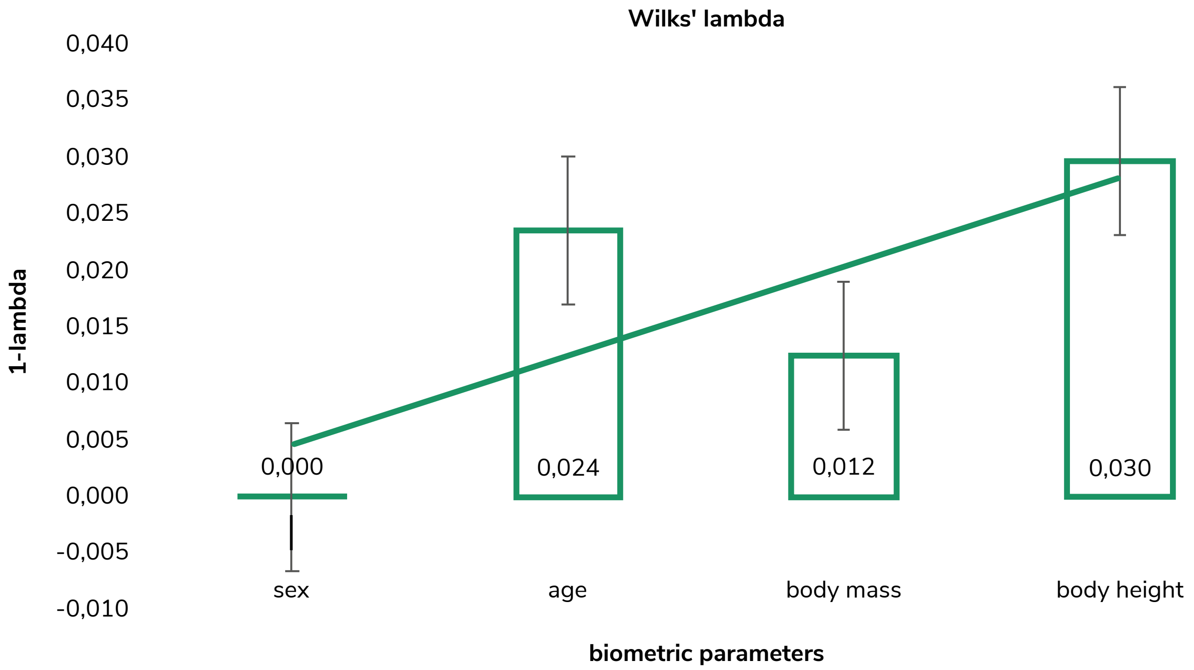

Figure 5. The summary of the discriminant function analysis for Variant I on the right side.

Discussion

Evaluating motor function in preschool children has become increasingly popular in recent years. It is recognized that motor dysfunction is associated with cognitive, language, social, and emotional difficulties and has an impact on the quality of life in later stages [13]. The strength and function of muscles in preschool age are most commonly assessed through the prism of global movement patterns typical for this age group (walking, running, standing on one leg, jumping). An example of such an assessment method is the Movement Assessment Battery for Children-2 (MABC-2) [14]. MABC-2 is a validated and norm-referenced test designed to detect motor coordination difficul-

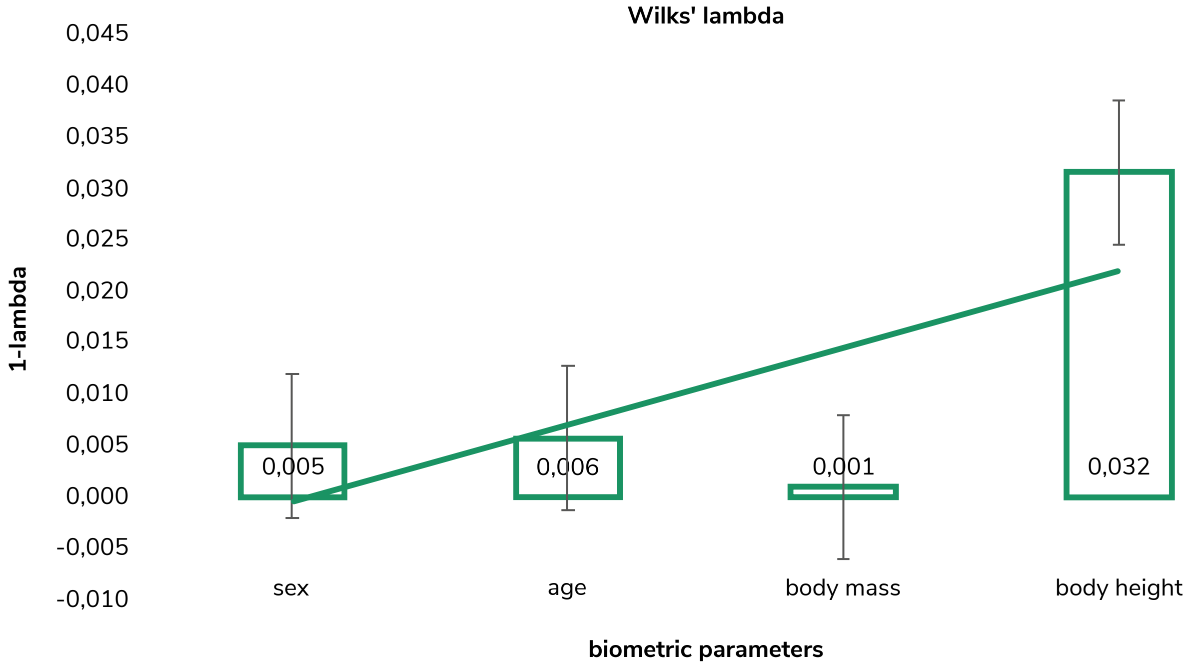

Figure 6. The summary of the discriminant function analysis for Variant II on the right side.

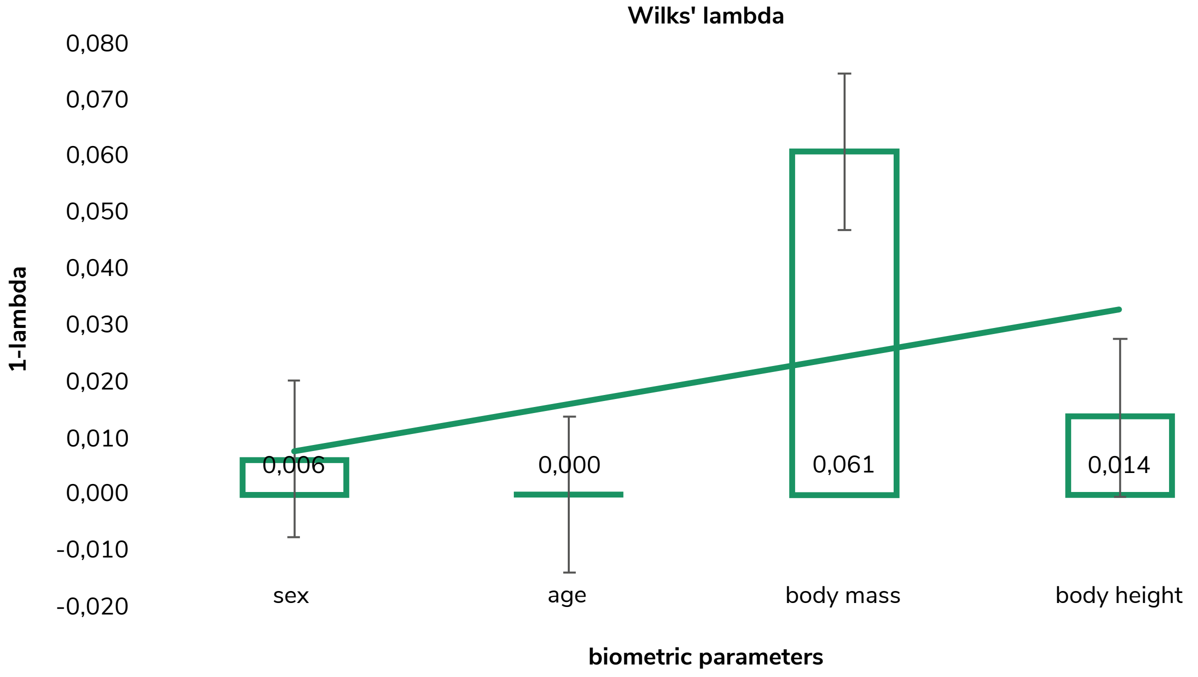

Figure 7. The summary of the discriminant function analysis for Variant IV on the right side.

ties in children aged 3-16 and is recommended for identifying developmental coordination disorders [15]. Another way to assess motor skills is the Zurich Neuromotor Assessment-2 (ZNA-2). The scale was developed for children aged 3-18 and covers the entire spectrum of a child's motor abilities from very poor to very good [7]. Such tools are the predominant form of assessment for preschool-aged children. However, considering a smooth transition from a global assessment of motor patterns in young children to a localized assessment of muscle function in older children and adults, attempts have been made to introduce manual testing even in the preschool group.

In the procedure developed for this project, the limb's own weight was considered as resistance. Stabilization was not applied during the test; instead, the child was taught to maintain the pelvis on the surface during the proprioceptive instruction. The magnitude of force required to initiate movement was recognized as a parameter that should be assessed during testing [16]. From the conducted observation, it emerged that only a portion of the children demonstrated the ability to perform the test according to the instructions (Variant I). In contrast, a significant portion carried out the task using alternative strategies (Variants II-IV). In Variant I, maintaining a bent angle of 90° at the knee joint minimizes the contribution of the hamstring muscles [10], resulting in an increased involvement of the gluteal muscles during the test task. In light of the theory established for adults, all other variants indicate reduced strength of the tested muscles and the incorporation of various compensatory mechanisms. However, analyzing the obtained results in the context of the variability theory as an expression of the norm in developmental age, all variants should be considered typical behaviors. It is essential to consider that variants with a more global character are more likely to occur in younger children, while in older ones, selective variants are predominant. Analyzing the percentage values in Group I, Variant IV was the most frequently chosen way of performing the test (39.30% on the right side), Variant II (37.92% on the right side), Variant III (34.72% on the left side), Variant I (34.08% on the left side). In Group II, the most frequently chosen were Variant III (55.00% on the right side), Variant I (44.00% on the right side, 40.59% on the left side), Variant IV (35.97% on the left side), Variant II (27.50% on the left side). Although the largest number of participants in the older age group chose Variant III, there was a noticeable increase in the percentage share of Variant I (on both sides).

Schmitt et al. [16] describe the types of compensations used during testing in adults, which can be employed to understand the strategies used in Variants II-IV. In Variant II, increased flexion in the knee joint activates the muscles of the hamstrings. In Variant III, increased extension in the knee joint contributes to the activation of the synergism of the hamstrings. Meanwhile, in Variant IV, the elevation and rotation of the pelvis indicate the recruitment of synergists: ipsilateral hamstrings and extensors of the thoracolumbar spine. However, a conclusive statement about whether the observed phenomenon is a form of compensation or a developmental norm could be obtained through longitudinal studies. Such observational studies would help determine whether there is a tendency to change strategies with age or if it remains constant, which could be considered a form of compensation.

The results of the discriminant analysis appear intriguing, revealing a clear tendency in the selection of test variants depending on certain biometric parameters. Height significantly influenced the choice of Variants I and II, suggesting that taller children utilize the strength of their gluteal muscles (Variant I) and/or the strength of gluteal and hamstring muscles (Variant II) to perform the task. The choice of Variant IV was notably influenced by body mass, implying that a substantial lower limb weight led to the recruitment of more muscles (ipsilateral hamstrings and extensors of the thoracolumbar spine) for task execution. In the case of Variant III, none of the factors showed a significant impact on its selectivity. Among the observed biometric parameters, only gender did not influence the selection of any variant.

Considering the challenges of conducting reliable MMT in preschool children, there is a lack of positions describing reference values for assessing the strength of individual muscles. In the literature, only attempts at MMT in children related to specific clinical conditions exist. Additionally, controversies exist among authors regarding using the MMT as a measurement tool for assessing muscle strength in children. Florence et al. [17] suggest that MMT assessments obtained on the Medical Research Council (MRC) scale are reliable when recorded by the same trained examiner. Such conclusions arise from studies conducted on a sample of children with Duchenne muscular dystrophy. It was recognized that the degree of reliability depends on the muscle group being examined. If MMT assessments are to be used for clinical decision-making, the authors recommend documenting their reliability by employing different testing methods [17]. Escolar et al. [18] compared the reliability of MMT and quantitative muscle testing (QMT). The authors concluded that QMT provides a better measure of muscle strength assessment for children with neuromuscular disorders compared to MMT. On the other hand, a systematic review conducted by Clark et al. [9] does not recommend any reliable form of muscle strength assessment for children and adolescents with neurological disorders.

Considering both clinical experience and evidence from the literature, it is important to remember that a significant portion of the assessment and treatment of patients using MMT is and will always remain an art, largely dependent on the examiner's experience. Assessments obtained during manual muscle testing are, to a considerable extent, subjective and depend on various factors, including the age of the patient, the nature of the issue, and the patient's cognitive and emotional factors. However, efforts should be made to provide a solid scientific foundation for these activities. Therefore, manual testing requires standardizing conditions, as the examiner must develop an empirical model against which the results of the tested muscle groups will be compared. The ability to conduct tests and draw appropriate conclusions is a conceptually important component of physiotherapeutic procedures [3].

Study limitations

The limitation of this project lies in its cross-sectional design rather than being longitudinal. Observing developmental variability over time would allow for addressing uncertainties arising from the discussion. Another area for improvement is the overly general criteria for inclusion in the observational group. The selection of healthy children should be preceded by basic tests indicating typical motor skills for their age (e.g., two-legged jumps, squats, standing on one leg).

Conclusions

In the group of typically developing preschool-aged children (from the completion of the third year to the beginning of the seventh year), four variants of performing the test for gluteal muscle strength are observed. However, variants requiring the engagement of a greater number of muscle groups (Variant IV) are more frequently chosen in the younger children's group. Conversely, in the older children's group, there is an increased preference for a more selective form of task execution (Variant I). Specific biometric parameters (age, height, body weight) significantly influenced individual test variants' selectivity. Gender did not impact the selectivity of any tested Variant.

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