Normative Assessment of Vastus Medialis Oblique Muscle Strength and its Relationship with Knee Extensor Strength in Healthy Young Adults: A Hand-Held Dynamometry Study

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Abstract

Background:
Patellofemoral pain syndrome represents one of the most prevalent knee conditions, with reported prevalence rates ranging from 7.2% to 35.7% across different populations. Muscle imbalances or weakness around the knee joint during flexion and extension movements constitute a primary aetiology of anterior knee pain. Quantitative muscle testing using handheld dynamometry enables the establishment of normative strength values for knee extensors and vastus medialis oblique muscles in healthy young adults.

Novelty:
Given the high prevalence and clinical significance of patellofemoral pain syndrome as a leading cause of knee dysfunction in young adults, this study establishes comprehensive normative values for vastus medialis oblique (VMO) and knee extensor muscle strength in healthy young adults using standardized handheld dynamometry protocols. These normative values provide essential reference data for early detection, clinical assessment, and evidence-based rehabilitation planning in patellofemoral pain syndrome management.

Purpose of the study:
To investigate the correlation between vastus medialis oblique muscle strength and knee extensor muscle strength using handheld dynamometry in healthy young adults and establish normative reference values.

Methods:
This cross-sectional study included 200 asymptomatic young adults aged 18-25 years (both males and females) who provided negative responses to screening questionnaires and participated voluntarily. Following informed consent, demographic data, limb dominance, height, and weight were recorded. Knee extensor and vastus medialis oblique muscle strength measurements were performed using a handheld dynamometer with standardized stabilization and positioning protocols.

Results:
Gender demonstrated weak correlations with both VMO and knee extensor strength (correlation coefficients: $r = 0.066$ to -0.088). Knee extensor strength measurements revealed distinct patterns between genders. Male participants demonstrated higher strength values on their dominant side (19.41 ± 7.89 kg) compared to their non-dominant side (18.16 ± 4.12 kg). Female participants

exhibited more consistent bilateral values, with 18.14 ± 4.25 kg on the dominant side and 18.12 ± 4.52 kg on the non-dominant side.

Discussion:

The established normative values provide clinicians with essential reference points for assessing pathological conditions, setting appropriate rehabilitation goals, and monitoring progress in strength training programs. These findings contribute to evidence-based clinical decision-making in knee rehabilitation.

Keywords:

Hand-Held Dynamometer, Knee Extensors, Vastus Medialis Oblique, Normative Strength Values, Patellofemoral Pain Syndrome

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Introduction

Patellofemoral pain syndrome (PFPS), also known as anterior knee pain, is a prevalent condition affecting 15% to 45% of young adults[1,2]. It represents one of the most frequently encountered knee disorders, constituting approximately 25% of all knee injuries treated in sports medicine clinics[3]. Anterior knee pain in young adults has been observed to potentially progress to various patellofemoral diseases[4]. Among the contributing factors to its aetiology, muscle weakness around the knee joint and patellar malalignment during knee flexion and extension play significant roles[5,6].

The assessment of maximal muscular strength and power is fundamental to physical therapy and rehabilitation practices[7]. Muscle strength, defined as skeletal muscle's force-generating capacity, is crucial for musculoskeletal system stability and mobility, facilitating efficient movement[8]. Furthermore, muscle strength has been identified as an independent predictor of clinical and functional improvement in physical rehabilitation[9]. Accurate patient impairment assessment requires comparison with reference values, particularly normative reference values, typically presented as means and standard deviations[10]. These values commonly include isometric maximum voluntary contraction forces or torques produced by asymptomatic individuals[11].

The quadriceps femoris, comprising the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius muscles, is responsible for knee extension[12]. The vastus group generates approximately 80% of the total knee extension torque, with the rectus femoris contributing the remaining 20%[13]. Together with the patella and patellar ligament, these muscles form the knee extensor mechanism[14].

The vastus medialis exhibits a complex fiber arrangement of oblique and longitudinal fibers[15]. Studies on vastus medialis activation during knee extension exercises, using electromyographic amplitudes expressed as maximum voluntary isometric contraction (MVIC) percentages, have

shown that single-leg stance with full knee extension requires minimal vastus medialis activation (6 ±3% MVIC), while flexion to 30 degrees results in greater activation (16 ±7% MVIC)[16].

Biomechanical studies indicate that muscle fiber activation and force generation efficiency vary based on structural attachments and moment arm direction[17]. In conditions such as PFPS, anterior knee pain, ACL tears, and post-operative knee extension lag, faulty arthrokinematics contribute to inefficient force generation during knee extension[18]. In PFPS, excessive lateral patellar tracking, potentially resulting from chondromalacia patellae, may occur due to medial soft tissue laxity and vastus medialis weakness[19]. Consequently, physical therapists typically focus on restoring vastus medialis oblique strength to improve function[20].

While numerous studies have established normative values for quadriceps muscle strength using handheld dynamometry[21], there remains a notable gap regarding specific normative values for the vastus medialis oblique muscle. Given its crucial role in patellar stabilization and torque production, determining these values and their correlation with quadriceps strength in healthy young adults is imperative[22].

The primary objective of this study is to determine the normative value for vastus medialis oblique muscle strength using handheld dynamometry in healthy young adults. Secondly to investigate the correlation between vastus medialis oblique muscle strength and knee extensor muscle strength using handheld dynamometry in healthy young adults.

Methods

Following the ethical clearance and approval by the Institutional Research Cell, Brainware University, Ref No. BWU/AHS/NTC/MSL/2023/006 from Brainware University, Barasat, Kolkata-125, a cross-sectional observational study was conducted by distributing a public notice through the Department of Allied Health Sciences inviting volunteers aged 18-25 years. Two hundred volunteers (n = 131 males, n = 69 females) who met the inclusion criteria and gave consent were enrolled, convenience sampling for the study. The mean age was 20.13 ± 1.61 years for males and 19.90 ± 1.33 years for females. The volunteer included those gave negative responses to following questions: Age between 18-25 years, no current or previous pathology affecting muscle force, Inability to walk 30.5 m independently without assistive devices, no limiting conditions affecting upper or lower extremity strength testing. The volunteers with Current treatment for heart, lung, nervous system, bone, or joint problems, Inability to complete strength testing, positive response to any health screening questions were excluded from the study.

Instrumentation: - Force measurements were conducted using a wireless MicroFET®2 portable dynamometer[23] (Fig. 1) with a maximum capacity of 300 lb (136.07 kg). The device was calibrated and verified by the manufacturer post-investigation using a calibration-check fixture with standardized 100-pound weights. Digital conversion scaling was based on load cell recordings measured in kilograms and stored in programmable read-only memory[24].

Figure: 1- Wireless MicroFET®2 portable dynamometer

Testing Procedures

The vastus medialis obliques muscle strength assessment was conducted with the participants in a half-lying position with 30- degree knee flexion maintained by using a towel roll beneath the knee, while the knee extensor group assessment is performed in high sitting with hip and knee flexed to 90 degrees and ankle in neutral. The both assessments were done by keeping the dynamometer perpendicular to the tested limb segment and proximal to malleoli, with an assistant provided for the shoulder stabilization. The testing protocol was begun with a familiarization trial, followed by an isometric “Make” test where the participants gradually build up force to maximum voluntary effort over 2 seconds and maintains it for 5 seconds, resulting in a total trial duration of 7 seconds. A rest period of 1-2 minutes is given between trials, with three recordings taken per muscle group, testing both dominant and non-dominant sides.

Statistical Analysis

All data analyses were performed using software SPSS program. As a preliminary to the determination of normative values for muscle strength, the importance of gender, weight, age and height examined the sample of subjects tested. The correlations between muscle strength were determined with Spearman’s rank correlation coefficients. Stepwise multiple regression procedures were performed provide prediction equation of muscle strength for both the dominant and non-dominant sides based on subject gender, weight, height, and age.

Table-1: Physical characteristics of all subjects

Table- 2: Demographic Characteristics

Table- 3: Correlation Analysis

Results

Demographic Characteristics

The study included 200 healthy young adults between 18-25 years of age. Male participants 131 demonstrated a mean age of 20.13 ± 1.61 years, with an average height of 167.30 ± 6.06 cm and weight of 66.02 ± 12.10 kg. Female participants 69 had a mean age of 19.90 ± 1.33 years, with an average height of 155.50 ± 5.72 cm and weight of 53.35 ± 10.24 kg.

Correlation Analysis

Analysis of the relationship between muscle strength measurements and demographic variables revealed minimal correlations. Gender showed weak correlations with both VMO and knee extensor strength, with correlation coefficients ranging from r = 0.066 to -0.088. Weight demonstrated similarly weak correlations, ranging from r = -0.114 to 0.064. Height showed a significant but weak correlation only with dominant side knee extensor strength ($r = 0.195$, $p < 0.01$), while correlations with other measurements remained negligible (r = -0.019 to 0.068).

Normative Strength Values

In male participants, the mean VMO strength for the dominant side was 16.41 ± 4.03 kg, while the non-dominant side indicates a slightly higher value of 16.90 ± 7.44 kg. Female participants demonstrated marginally higher VMO strength values, with 16.96 ± 3.80 kg on the dominant side and 17.35 ± 4.20 kg on the non-dominant side.

Knee extensor strength measurements revealed different patterns. Male participants exhibited higher values on their dominant side (19.41 ± 7.89 kg) compared to their non-dominant side (18.16 ± 4.12 kg). Female participants showed more consistent values between sides, with 18.14 ± 4.25 kg on the dominant side and 18.12 ± 4.52 kg on the non-dominant side.

Gender Comparison

The analysis revealed interesting patterns in strength distribution between genders. While absolute knee extensor strength values were generally higher in males, particularly on the dominant side, VMO strength showed less gender-based variation. This finding suggests that the relative contribution of the VMO to overall knee extension strength may differ between genders.

Side-to-Side Comparison

Side-to-side comparisons revealed minimal differences in VMO strength for both genders. However, knee extensor strength showed greater variability between dominant and non-dominant sides, particularly in male participants. This asymmetry was less pronounced in female participants, who demonstrated more consistent strength values between sides.

These findings indicate that while overall knee extensor strength may vary between sides and genders, VMO strength remains relatively consistent across these parameters. This observation suggests that VMO strength may be regulated by factors different from those controlling overall knee extensor strength.

Values presented as Mean ± SD in kilograms

Table-4

Discussion

Muscle strength evaluation is fundamental understanding of musculoskeletal biomechanics and to the design of focused rehabilitation programs. The VMO muscle is crucial in the stability of the knee joint and patellofemoral mechanics, making the strength characteristics of this muscle of great importance in clinical and sports medicine settings.[8,14]

This study provides insights regarding normative values of VMO muscle strength and knee extensor muscle strength in young healthy adults with the use of the exact measurement technique of hand-held dynamometry. [11,23]

Characteristic Strength Features

One of the major findings is that the strength of VMO and knee extensors are different in nature. The strength of the VMO muscle is very consistent whereas that of the knee extensors is highly variable[13],[17]. Physiological mechanism regulating VMO muscle strength might differ from the one that regulates the overall strength of knee extensors.

Minimal differences between dominant and non-dominant sides are indications of potential functional symmetry in VMO muscle performance. This is critical to stability in the knee joint as well as in the patellofemoral mechanics [14]. In earlier studies, this phenomenon corresponds with findings on the complexity of vastus medialis fiber distribution including both oblique and longitudinal orientations [15].

The lack of significant correlation between VMO strength and overall knee extensor strength suggests that these measurements may represent distinct functional aspects of knee mechanics. This finding has important implications for clinical assessment and rehabilitation strategies, particularly in conditions where selective VMO strengthening is indicated [25].

Strength Variations and Biomechanical Considerations

Greater variability was noted for knee extensor strength, which would be expected from biomechanical research in which muscle activation and force production can be different from each other in terms of the structural connections or movement patterns[17]. The quadriceps femoris is a composite muscle that generates knee extension torque, and about 80% of this total torque is provided by the vastus group[12].

The established normative values are of interest - VMO strength showed minimal side-to-side differences in both genders, Female subjects had higher VMO values compared to their knee extensor strength than males, Knee extensor strength values agree with published reports[26],[27]. These normative values, thus, validate our measurement methodology and can be used by clinicians as a reference for: Evaluation of pathological conditions, setting of rehabilitation goals, Monitoring of strength training programs.

Minimal gender-based differences in strength ratios in the VMO were reported, although absolute strength values differed according to expectation. This indicates that perhaps relative contribution to knee extension might be consistent between genders and suggests that similar relative strength targets can be applied regardless of gender in rehabilitation programs.

In the framework of Patellofemoral Pain Syndrome (PFPS), our findings have important implications for understanding and managing the condition of patellofemoral pain syndrome, which affects 15% to 45% of young adults[1],[2]. In PFPS, medial soft tissue laxity and vastus medialis weakness can lead to excessive lateral patellar tracking[19]. The consistency in VMO strength observed would suggest that interventions targeting the activation of the VMO muscle might be critical in the prevention and management of this condition[20].

Previous studies have also shown that delayed onset of VMO activation relative to other quadriceps muscles results in the development of patellofemoral pain[20]. This study established

normative values to help clinicians and physical therapists create a benchmark for assessing muscle strength and designing rehabilitation strategies[29].

The use of hand-held dynamometry has evidence of reliability in being used as a clinical tool to assess muscle strength. Stark et al. (2011) conducted a systematic review that validated the correlation between hand-held dynamometry and the gold standard, isokinetic dynamometry, in order to validate the method for both clinical and research use[7].

Gender and Strength Considerations, The study found little to no difference in the VMO strength ratios based on gender where there were presumed to be differences in the absolute values. This suggests that maybe the relative contribution of VMO to knee extension might not vary with genders and justify similar relative strength goals being pursued in rehabilitation programs[28].

Our results have some practical clinical implications: Established normal values can be used for diagnosis and detection of weakness in a patient population, The independence of strength in the VMO and general extensors of the knee supports specific VMO targeting in rehabilitation programs, in particular, since there were similar patterns between dominant and non-dominant limbs, in some cases, it could serve as a valid comparison to reference in unilateral cases.

This study provides useful insights but also has limitations. The convenience sampling method and the narrow age range of 18-25 years limit the generalizability of the results, and the cross-sectional design precludes longitudinal analysis of changes in strength. In addition, the measurement technique, while clinically practical, may introduce variability, and there is a need for future research to enhance external validity and depth of analysis.

Conflict of Interest: There is no conflict of interest.

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Figure-1 Wireless MicroFET®2 portable dynamometer

Table-1 Physical characteristics of all subjects

Gender	Age (Years)		Height (Cm)		Weight (Kg)	
	Mean	SD	Mean	SD	Mean	SD
Male	20.13	1.605	167.30	6.062	66.017	12.10
Female	19.90	1.330	155.50	5.716	53.351	10.24

Table- 2: Demographic Characteristics

Characteristics	VMD	VMND	KED	KEND
Age	.098	.022	.058	-.060
Gender	.066	.032	-.088	-.005
Weight	-.114	-.105	.064	-.137
Height	-.019	.068	.195**	.018
**. Correlation is significant at the 0.01 level (2-tailed).				

Table- 3: Correlation Analysis

	Normative value	
Descriptive Statistics	Mean	Std. Deviation
VMOD M	16.4141	4.02909
VMO D F	16.9572	3.79753
VMO ND M	16.9045	7.43776
VMO ND F	17.3464	4.19617
KE D M	19.4124	7.89204
KE D F	18.1393	4.24706
KE ND M	18.1600	4.12278
KE ND F	18.1159	4.52071
VMO - Vastus medialis obliques, KE - Knee extensor, D - Dominant side, ND - Non dominant side, F - Female, M - Male		

Table-4 Correlation analysis of dominant and non-dominant side

Muscle Group	Gender	Dominant Side	Non-Dominant Side
VMO	Male	16.41 ± 4.03	16.90 ± 7.44
	Female	16.96 ± 3.80	17.35 ± 4.20
Knee Extensor	Male	19.41 ± 7.89	18.16 ± 4.12
	Female	18.14 ± 4.25	18.12 ± 4.52