

Correlations Between Muscle Group Strengths and Basic Functional Abilities in Inclusion Body Myositis: A Pilot Study

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Abstract

Background: We aimed to examine the correlation between lower-extremity muscle strength and the ability to perform basic functional activities in individuals with inclusion body myositis (IBM).

Methods: We examined how muscle strength correlates with basic functional abilities in 18 participants with IBM. Isometric strength across seven muscle groups was measured using a handheld dynamometer. Functional performance was assessed through gait, standing-up, and stair-negotiation abilities.

Results: Gait ability was associated with strength in hip flexion, hip extension, hip abduction, and knee flexion. Standing-up ability correlated with knee extension strength. No notable correlation existed between muscle strength and stair-climbing ability. All participants relied on upper limb support during stair descent.

Conclusions: Participants possibly employed compensatory strategies, engaging hip and knee flexor muscles for walking support; standing up appeared to depend on knee extension strength. These insights support focused rehabilitation targeting specific muscle groups and improved clinical assessments to preserve function in IBM.

Keywords: gait, muscle strength dynamometer, inclusion body myositis

1. Introduction

Inclusion body myositis (IBM) is a chronic progressive muscle disease typically manifesting in middle-aged and

older adults aged >50 years (1-6). Histopathological analysis of skeletal muscle tissue reveals characteristic rimmed vacuoles, accompanied by inflammatory cell infiltration. In addition to these inflammatory features, mitochondrial dysfunction and oxidative stress are increasingly recognized as important contributors to the degenerative component of IBM pathology (7). Muscle weakness is the most distinctive clinical finding in IBM. This weakness, with associated muscle atrophy, primarily involves the quadriceps femoris and finger and wrist flexor muscles, raising clinical suspicion for IBM, although this distribution is not fully specific for diagnosis (1, 3, 4, 6).

With disease progression, muscle strength gradually deteriorates, leading to increasing difficulty in performing activities of daily living. Patients commonly report difficulty with rising from a chair, climbing stairs, entering a car, lifting objects, washing their hair, brushing their teeth, and gripping items (1). IBM is generally refractory to immunosuppressive therapy, in contrast to other inflammatory myopathies, indicating a complex pathogenesis involving inflammatory and degenerative processes (1, 8, 9).

Adequate lower-limb muscle strength, particularly involving the quadriceps, is essential for basic functional activities such as walking, sit-to-stand transitions, and stair climbing; strength thresholds below which performance markedly declines have been identified (10-13), and quadriceps strength correlates strongly with functional mobility measures such as gait speed, chair-rise time, and stair-climbing time (14-18). Largely, patients with IBM maintain their ambulatory ability for extended periods, and complete wheelchair dependency occurs in only 3% of patients (1). However, a wheelchair is reportedly needed by about one-third of patients within 14 years of onset, and by nearly all patients within 20 years — a considerably higher proportion than the overall 3% figure suggests (4). This finding suggests that certain compensatory mechanisms, or the relative preservation of other muscle groups may play important roles in maintaining functional mobility in these patients.

Preservation of walking ability, despite marked quadriceps weakness, presents a clinical paradox that requires further investigation. This study aimed to examine the correlation between lower-extremity muscle strength and the ability to perform three essential basic functional activities—gait, standing up, and stair negotiation—in individuals with IBM. We defined basic functional activities as fundamental motor tasks required for independence in activities of daily living, occupational engagement, and community participation. These activities are characterized by being repetitive, essential for autonomy, and representatively challenging for patients with proximal muscle weakness such as IBM. As a pilot study, the findings of the present study will inform the design of larger studies on the functional implications of muscle weakness in IBM.

2. Methods

2.1 Ethical approval and informed consent

The study was approved by the Ethics Committee of our institution on April 19, 2022 (approval number: A2022-003). This study was conducted in accordance with the principles of the Declaration of Helsinki and its amendments and followed the STROBE reporting guidelines for observational studies. Written informed consent was obtained from all participants for study participation and publication of their de-identified data.

2.2 Study design

This study was conducted between May 2022 and December 2023 at our institution. Eighteen participants with IBM were included. The inclusion criteria were as follows: (1) adults aged ≥ 18 years and (2) a history of achieving ambulatory ability during development. Although IBM typically manifests in adults older than 50 years, we set the lower age threshold at 18 years to remain inclusive of the full adult range. The exclusion criteria included: (1) cognitive impairment, defined as a Mini-Mental State Examination score ≤ 24 , and (2) muscle weakness resulting from non-myopathic etiologies.

Participants were hospitalized patients diagnosed with IBM by experienced neurologists in the Department of Neurology at our institution, based on established clinical and histopathological features of IBM. Participants were recruited from the inpatient rehabilitation ward following their receipt of a rehabilitation prescription from rehabilitation physicians. The treating physical therapist approached eligible patients and obtained written informed consent from those willing to participate.

Basic demographic and clinical data were collected, including sex, age, height, weight, body mass index (BMI), age at disease onset, disease duration, and the IBM Functional Rating Scale (IBM-FRS) scores (19, 20).

2.3 Tasks and procedures

2.3.1 Assessor training protocol

All physical therapists conducting muscle strength assessments ($n=6$, each with ≥ 5 years clinical experience) underwent standardized training to ensure measurement consistency. Prior to data collection, all assessors completed a joint training protocol in which they performed repeated measurements on the same healthy volunteers until they achieved agreement in dynamometer readings. Although six physical therapists conducted assessments due to clinical scheduling requirements, the bilateral measurements for all muscle groups in each participant were obtained by the same assessor to minimize inter-rater variability for individual participants. This approach ensured consistency within participants while allowing for clinical feasibility.

2.3.2 Assessment procedures and blinding

Functional ability assessments were conducted in a separate location or after an interval, thereby minimizing

potential bias. Testers' knowledge of participant functional status was limited to incidental gait observation during transfer between testing areas; standing-up and stair-negotiation abilities were assessed without prior knowledge of participant capabilities.

2.3.3 Muscle strength assessment

Regarding the rationale involving muscle group selection, the focus remained on muscle groups directly involved in the basic functional abilities of individuals with IBM, including gait, sit-to-stand transitions, and stair negotiation. The Manual Muscle Testing 8 (MMT8) clinical tool, recommended by the International Myositis Assessment and Clinical Trials Group as a core outcome measure for idiopathic inflammatory myopathies, evaluates eight muscle groups: the deltoids (shoulder abduction), biceps (elbow flexion), ankle dorsiflexors (ankle dorsiflexion), gluteus maximus (hip extension), gluteus medius (hip abduction), quadriceps (knee extension), wrist extensors (wrist extension), and neck flexors (neck flexion) (21, 22). From these, the upper-limb muscle groups—the deltoids, biceps, and wrist extensors—were excluded. Knee flexors (knee flexion) and ankle plantarflexors (ankle plantarflexion) were included due to their essential role in walking and rising from a seated position (23–27). This modification provided a more comprehensive assessment of lower-extremity function, which is central to understanding the correlation between muscle strength and basic functional abilities in individuals with IBM, a condition characterized by proximal muscle weakness that severely impacts mobility.

Isometric muscle strength was assessed using a hand-held dynamometer (HHD; (microFET², Hoggan Scientific, Salt Lake City, Utah, USA) for the following seven muscle-group joint-specific movements: hip flexion, extension, and abduction; knee flexion and extension; and ankle plantarflexion and dorsiflexion. Each muscle-group joint-specific movement was measured twice for 5 s each time. Between measurements, participants were asked about fatigue and given brief rest periods (approximately 30 s) to ensure recovery before the next measurement. If the two measurements differed by $>15\%$, a third trial was conducted to ensure measurement reliability and reduce variability in strength estimates.

HHD was selected for measuring isometric muscle strength based on scientific validity and clinical practicality (Itoh et al., 2025; Stark et al., 2011). Although surface electromyography provides detailed information on muscle activation patterns, it is impractical for comprehensive multi-muscle assessment in a clinical setting. In contrast, HHD offers superior clinical utility as a portable, practical tool for assessing multiple muscle groups, with advantages such as time efficiency, cost-effectiveness, immediate quantifiable results, and suitability for fatigable patients (Bohannon, 2012). These characteristics made HHD ideal for this pilot study examining seven lower-extremity muscle groups in patients with IBM who may experience fatigue during prolonged testing procedures.

Table 1. Demographic and clinical characteristics of study participants. Data are presented as medians [25–75% interquartile range], unless otherwise specified. IBM-FRS; inclusion body myositis functional rating scale.

	All Patients	Gait Ability		Standing-up Ability		Stair-climbing Ability	
Total	n=18	Unable n=4	Able n=14	Unable n=13	Able n=5	Unable n=16	Able n=2
Male, % (n)	55.6 (10)	0.0 (0)	71.4 (10)	53.8 (7)	60.0 (3)	56.3 (9)	50.0 (1)
Female, % (n)	44.4 (8)	100.0 (4)	28.6 (4)	46.2 (6)	40.0 (2)	43.8 (7)	50.0 (1)
Age, years	65.5 [60.0–74.0]	74.5 [65.5–76.5]	62.5 [60.0–71.0]	68.0 [62.0–74.0]	63.0 [60.0–71.0]	68.5 [59.5–74.5]	61.5 [60.0–63.0]
Height, cm	163.2 [156.0– 171.4]	153.3 [148.8–159.2]	165.8 [156.2– 171.6]	162.3 [156.0–166.5]	171.6 [156.2– 172.0]	163.2 [156.0– 169.3]	164.0 [156.0– 172.0]
Weight, kg	54.9 [45.0–59.4]	40.9 [36.0–50.5]	55.6 [46.0–64.7]	54.8 [45.0–64.7]	55.0 [45.7–58.1]	55.4 [45.4–62.0]	49.5 [43.9–55.0]
BMI, kg/m ²	19.6 [18.6–21.2]	18.4 [15.2–21.4]	19.6 [18.7–21.2]	20.2 [18.9–23.0]	18.7 [18.6–19.0]	19.8 [18.8–22.1]	18.3 [18.0–18.6]
Age at onset, y	59.0 [51.0–63.0]	59.5 [51.0–61.5]	59.0 [51.0–65.0]	59.0 [50.0–63.0]	59.0 [57.0–66.0]	59.5 [50.5–64.0]	58.0 [57.0–59.0]
Duration, years	8.0 [4.0–14.0]	14.5 [12.5–17.0]	6.5 [4.0–8.0]	11.0 [7.0–15.0]	5.0 [4.0–6.0]	8.0 [4.5–14.5]	3.5 [1.0–6.0]
IBM-FRS	25.0 [21.0–31.0]	15.0 [9.0–21.0]	29.0 [25.0–32.0]	21.0 [15.0–28.0]	31.0 [25.0–32.0]	25.0 [21.0–30.0]	31.5 [31.0–32.0]

Muscle strength measurements followed the standardized positions outlined in the Hoggan Scientific Muscle Testing Positions guide for the microFET (Hoggan Scientific, USA: <https://hogganscientific.com/wp-content/uploads/2019/06/HogganScientific-MuscleTestingPositions-11x17-Poster.pdf>). To assess hip flexion, the participant was positioned supine with the hip flexed to 90°; the HHD was placed immediately proximal to the femoral condyles. To measure hip extension, the participant was positioned supine, with the knee extended and the distal limb supported on a block; the dynamometer was placed immediately distal to the malleoli over the Achilles tendon. To evaluate hip abduction, the participant was positioned supine, with the hip extended and in a neutral position; the dynamometer was placed proximal to the lateral knee joint line. To measure knee extension, the participant was seated, with the hip and knee flexed to 90°; the dynamometer was positioned proximal to the malleoli. To measure knee flexion, the participant remained seated, with the hip and knee flexed to 90°, and the dynamometer was placed immediately distal to the malleoli over the Achilles tendon. To assess ankle plantarflexion, the participant was positioned supine, with the knee extended and ankle in neutral

dorsiflexed position; the dynamometer was placed over the metatarsophalangeal joints. To assess ankle dorsiflexion, the participant remained supine, with knee extended and ankle in neutral dorsiflexion; the dynamometer was positioned proximal to the metatarsophalangeal joints.

2.3.4 Functional ability assessment

Functional ability was assessed through three basic activities: gait, standing up, and stair negotiation. All functional assessments were conducted with the participants wearing their comfortable athletic shoes to simulate real-world conditions.

2.3.4.1 Gait assessment

Regarding gait, participants who walked independently within the hospital without supervision or assistive devices were categorized into the “able” cohort.

2.3.4.2 Standing up assessment

Participants sat on a chair adjusted to achieve 90° knee flexion, with the arms folded across the chest. They were instructed to stand without using momentum, which was defined as avoiding excessive trunk acceleration. Participants

who successfully stood up at least once out of three attempts were categorized into the “able” cohort.

2.3.4.3 Stair negotiation assessment

Participants who continuously ascended 16 steps (each step 18 cm high), placing one foot on each step without using handrails or touching the walls with either upper limb, were categorized into the “able” cohort for stair ascent; those who required upper-limb support during ascent were categorized as “unable.” Compensatory movements, such as knee locking during ascent, were permitted. Stair descent was assessed separately using the same 16-step protocol and criteria. Because all participants required upper-limb support to descend, no participant met the “able” criterion for descent; stair descent was therefore excluded from the subsequent able/unable comparisons, and stair-negotiation results reported below refer to ascent performance only.

2.5 Muscle strength normalization

Regarding bilateral measurements, the average left and right limb values were calculated and used in all statistical analyses. The average force value, measured in kilogram-force (kgf), was divided by body weight (kg) to calculate the muscle strength-to-weight ratio (kgf/kg) for standardization.

2.6 Data analyses

Point-biserial correlation coefficients (r) were calculated to analyze the correlation between muscle strength-to-weight ratios and functional abilities, categorized as able or unable, for each basic activity. This statistical method

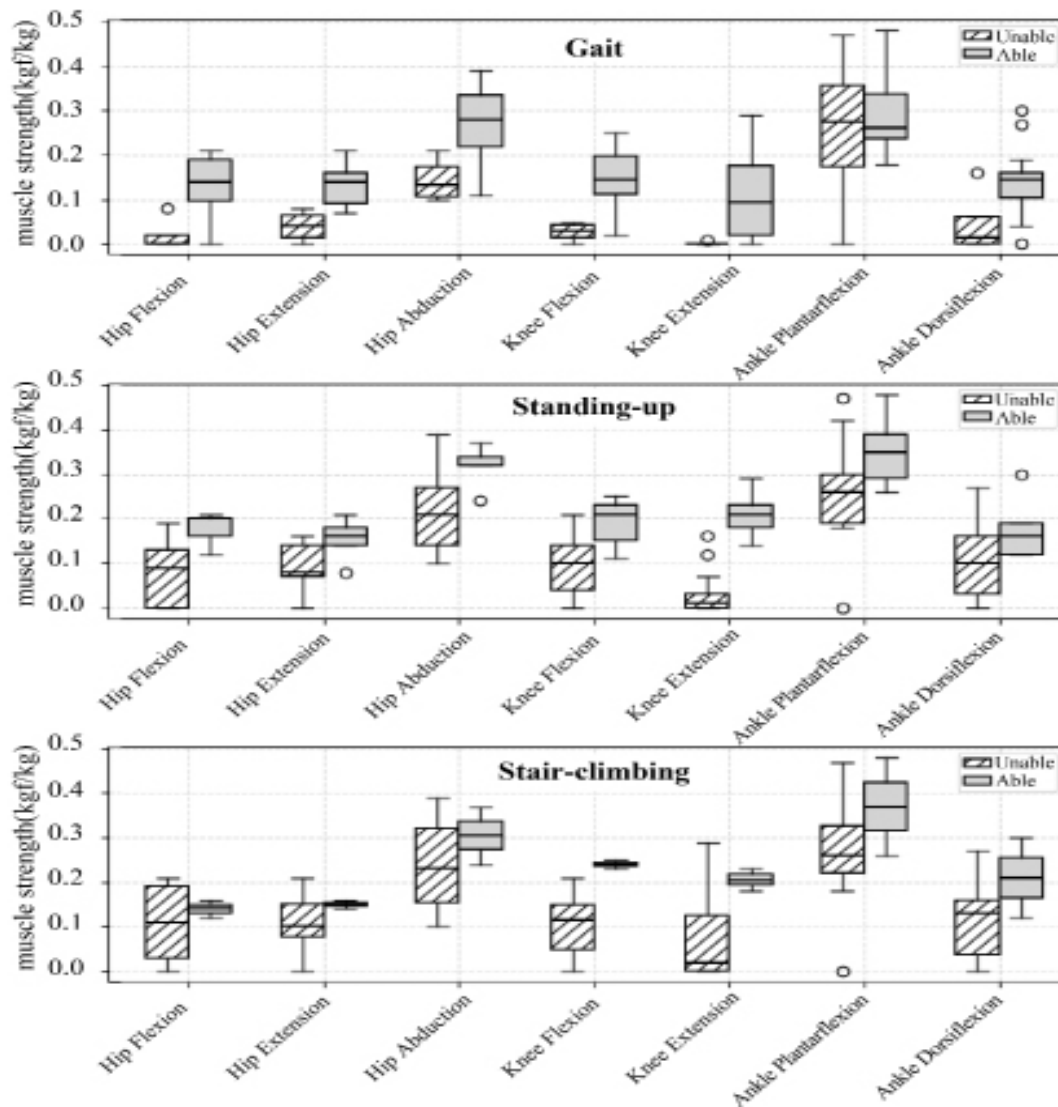
is appropriate for examining relationships between one continuous variable (muscle strength) and one dichotomous variable (binary functional categorization). To control for multiple comparisons and reduce the risk of Type I errors, the Benjamini–Hochberg correction was applied separately to each functional activity. The 95% confidence intervals (CIs) for r values were calculated using bootstrap resampling (5,000 iterations) because of the small sample size ($n = 18$). For each iteration, we resampled with replacement from the original data and recalculated the correlation coefficient. The 95% CI was defined by the 2.5–97.5th percentiles of the bootstrap distribution, which does not assume normality of the correlation coefficients. Additionally, non-parametric Mann–Whitney U tests were used to compare muscle strength between participants in the able and unable groups for each functional activity.

Correlations were interpreted using the following categories based on established methodology: values from 0.00 to 0.30 and 0.00 to -0.30 indicated negligible correlation; 0.30 to 0.50 and -0.30 to -0.50 indicated low correlation; 0.50 to 0.70 and -0.50 to -0.70 indicated moderate correlation; 0.70 to 0.90 and -0.70 to -0.90 indicated high correlation; and 0.90 to 1.00 and -0.90 to -1.00 indicated very high correlation (28). This approach enabled standardized interpretation of the strength of correlations between muscle groups and basic functional abilities. All statistical analyses were performed using Python 3.11 (Python Software Foundation, Wilmington, DE, USA). Statistical significance was set at $p < 0.05$.

Table 2. Relationship between muscle strength-to-weight ratio (kgf/kg) and basic functional abilities. *Results are expressed as medians [25–75% interquartile range] for continuous variables.*

	All Patients	Gait Ability		Standing-up Ability		Stair-climbing Ability	
(kgf/kg)	n=18	Unable n=4	Able n=14	Unable n=13	Able n=5	Unable n=16	Able n=2
Hip Flexion	0.13 [0.04–0.19]	0.00 [0.00–0.04]	0.14 [0.09–0.19]	0.09 [0.00–0.13]	0.20 [0.16–0.20]	0.11 [0.02–0.19]	0.14 [0.12–0.16]
Hip Extension	0.13 [0.08–0.16]	0.04 [0.01–0.07]	0.14 [0.08–0.16]	0.08 [0.07–0.14]	0.16 [0.14–0.18]	0.10 [0.08–0.15]	0.15 [0.14–0.16]
Hip Abduction	0.24 [0.16–0.32]	0.14 [0.11–0.18]	0.28 [0.21–0.34]	0.21 [0.14–0.27]	0.32 [0.32–0.34]	0.23 [0.15–0.32]	0.30 [0.24–0.37]
Knee Flexion	0.13 [0.05–0.16]	0.03 [0.01–0.04]	0.15 [0.11–0.21]	0.10 [0.04–0.14]	0.21 [0.15–0.23]	0.11 [0.04–0.15]	0.24 [0.23–0.25]
Knee Extension	0.03 [0.00–0.16]	0.00 [0.00–0.01]	0.10 [0.02–0.18]	0.01 [0.00–0.03]	0.21 [0.18–0.23]	0.02 [0.00–0.13]	0.21 [0.18–0.23]
Ankle Plantarflexion	0.26 [0.23–0.35]	0.28 [0.12–0.40]	0.26 [0.23–0.35]	0.26 [0.19–0.30]	0.35 [0.29–0.39]	0.26 [0.21–0.33]	0.37 [0.26–0.48]
Ankle Dorsiflexion	0.13 [0.04–0.16]	0.01 [0.00–0.10]	0.15 [0.10–0.16]	0.10 [0.03–0.16]	0.16 [0.12–0.19]	0.13 [0.04–0.16]	0.21 [0.12–0.30]

Figure 1. Comparative analysis of muscle strength-to-weight ratios between the able and unable cohorts across various functional activities. Muscle strength-to-weight ratios (kgf/kg) appear for seven muscle groups in patients with inclusion body myositis (IBM). The image compares those who are able to perform each activity (grey boxes) and those unable (hatched boxes) to do so across three functional activities: gait (top), standing up (middle), and stair climbing (bottom). Box plots show median values with interquartile ranges (25th–75th percentiles), and whiskers indicate the full range excluding outliers.



3. Results

Between May 2022 and December 2023, eligible participants with IBM were identified from the inpatient rehabilitation ward. All participants who met the inclusion criteria and provided informed consent were enrolled. A total of 18 participants completed the study; no participant was excluded after enrollment.

Participant characteristics are presented in Table 1, including demographic data and the distribution of participants categorized into the able and unable cohorts for each functional activity. Of the 18 participants, 14 were able to walk independently within the hospital, whereas four required assistance and were categorized as unable.

Regarding standing-up ability, five participants successfully stood from a seated position without using momentum, whereas 13 were unable to stand. Furthermore, regarding stair-climbing ability, only two participants ascended and descended 16 steps without support, whereas 16 were unable to independently complete the task. Notably, stair descent was assessed separately; none of the participants were able to complete the task without upper limb support, indicating that this activity was universally challenging for all participants with IBM.

The correlations between the participants' muscle strength-to-weight ratios and basic functional abilities are presented in Table 2 and Figure 1. For each muscle-group joint-

specific movement, with the exception of ankle plantarflexion for gait ability, participants in the “able” cohort consistently demonstrated higher median strength values than did those in the “unable” cohort across all three functional activities. Regarding gait ability, five muscle groups showed significant differences: hip flexion ($p = 0.01$), hip extension ($p = 0.007$), hip abduction ($p = 0.02$), knee flexion ($p = 0.008$), and knee extension ($p = 0.02$). Regarding standing-up ability, significant differences were found for knee extension ($p = 0.002$), hip flexion ($p = 0.01$), knee flexion ($p = 0.02$), hip abduction ($p = 0.04$), and hip extension ($p = 0.05$). Furthermore, regarding stair-climbing ability, only knee flexion showed a significant difference ($p = 0.03$), limited by the small number of participants that could complete the task ($n = 2$).

As shown in Table 3, point-biserial r values with 95% bootstrap CIs were calculated to examine the correlations between muscle strength and basic functional abilities. Statistically significant correlations after Benjamini–Hochberg correction were observed for gait ability with hip flexion ($r = 0.649$ [0.261–0.856]), hip extension ($r = 0.704$ [0.353–0.881]), hip abduction ($r = 0.564$ [0.132–0.816]), and knee flexion ($r = 0.663$ [0.284–0.863]). Regarding standing-up ability, statistically significant correlations were found with

hip flexion ($r = 0.569$ [0.139–0.818]) and knee extension ($r = 0.846$ [0.627–0.941]). No statistically significant correlations were observed for stair-climbing ability.

4. Discussion

In this study, we examined the correlations between muscle strength and the ability or inability to perform basic functional activities in patients with IBM. Our findings revealed distinct patterns of correlation between specific muscle groups and three fundamental activities: gait, standing up, and stair climbing. Regarding gait, moderate-to-high correlations emerged between muscle strength and functional ability, particularly involving hip flexion, extension, and abduction, as well as knee flexion. Hip extension showed the strongest correlation with gait ability ($r = 0.704$). Standing-up ability correlated most strongly with knee extension strength ($r = 0.846$). No notable correlations were observed between muscle strength and stair-climbing ability.

4.1 Hip extension as the primary determinant of gait ability

Moderate-to-high correlations between hip muscle strength and gait ability in participants with IBM suggest the presence of important compensatory mechanisms that

Table 3. Point-biserial correlation coefficients between muscle strength and functional abilities. Point-biserial correlation coefficients (r) with 95% bootstrap confidence intervals (CIs) [lower limit, upper limit] between muscle strength-to-weight ratios and performance in three functional activities in patients with inclusion body myositis. Raw and Benjamini–Hochberg-corrected p -values are presented. Asterisks (*) denote statistical significance after Benjamini–Hochberg correction ($p < 0.05$).

Ability	Gait		Standing-up		Stair-climbing	
	r [95% CI]	P-value p_{adj}	r [95% CI]	P-value p_{adj}	r [95% CI]	P-value p_{adj}
Hip Flexion	0.649* [0.261, 0.856]	0.004 0.02	0.569* [0.139, 0.818]	0.01 0.04	0.143 [-0.347, 0.572]	0.57 0.60
Hip Extension	0.704* [0.353, 0.881]	0.001 0.01	0.473 [0.007, 0.770]	0.05 0.09	0.244 [-0.252, 0.638]	0.33 0.36
Hip Abduction	0.564* [0.132, 0.816]	0.01 0.04	0.517 [0.066, 0.793]	0.03 0.07	0.245 [-0.251, 0.639]	0.33 0.36
Knee Flexion	0.663* [0.284, 0.863]	0.003 0.02	0.590 [0.170, 0.829]	0.010 0.06	0.575 [0.148, 0.821]	0.01 0.06
Knee Extension	0.460 [-0.009, 0.763]	0.05 0.09	0.846* [0.627, 0.941]	< 0.001 < 0.001	0.463 [-0.005, 0.765]	0.05 0.09
Ankle Plantarflexion	0.130 [-0.359, 0.563]	0.61 0.61	0.397 [-0.085, 0.729]	0.10 0.14	0.277 [-0.218, 0.659]	0.27 0.33
Ankle Dorsiflexion	0.473 [0.008, 0.770]	0.05 0.09	0.417 [-0.062, 0.740]	0.09 0.13	0.373 [-0.114, 0.715]	0.13 0.17

may have developed as the disease progressed. Hip extension strength showed the strongest correlation with gait ability ($r = 0.704$), likely reflecting an adaptation to compensate for quadriceps weakness, a hallmark of IBM (1, 5-7).

Participants appeared to rely on hip extension to shift the center of mass forward, thereby positioning the ground reaction force vector anterior to the knee joint. This biomechanical adaptation produces an external extension moment at the knee, which may aid in reduced quadriceps strength. The observed correlations of hip flexion, hip abduction, and knee flexion with gait ability provided additional evidence regarding compensatory strategies used by patients with IBM. Notably, the relatively wide CIs observed for these correlations, including hip flexion (0.261–0.856), hip abduction (0.132–0.816), and knee flexion (0.284–0.863), indicated substantial individual variability. This variability suggests that patients may engage different muscle groups or develop coordinated patterns of muscle activation, depending on their unique anatomical characteristics and the course of disease progression.

In contrast to patients with sudden-onset conditions such as stroke, patients with IBM experience a gradual progression of symptoms, allowing them to develop effective compensatory movement strategies. This gradual adaptation may explain why many patients with IBM retain ambulatory function despite marked quadriceps weakness, as previously reported (1).

4.2 Knee extension as the critical determinant of standing-up ability

The exceptionally high correlation between knee extension strength and standing-up ability ($r = 0.846$) confirmed the crucial role of the quadriceps muscle in this functional ability for participants with IBM. The lower threshold of the CI at 0.627 represents a moderate correlation, further supporting the robustness of this finding.

During the essential transition of the sit-to-stand movement from seated position to buttocks lift-off and through the momentum-transfer phase (29), the quadriceps contract concentrically to produce the knee extension moment necessary to elevate the body against gravity. As IBM progresses, compensatory mechanisms may develop. The biomechanical demands of buttocks lift-off require a threshold level of quadriceps strength. When quadriceps strength falls below this threshold, compensation becomes inadequate. This establishes knee extension strength as the primary determinant of standing-up ability in this population. In clinical practice, patients with advanced quadriceps weakness frequently use various compensatory strategies, including pushing down forcefully on the seat with their upper extremities or twisting their trunk to lock the knee joints. This enables them to stand up in a manner similar to the technique for Gowers' sign in patients with proximal myopathy. In contrast, hip extension and knee flexion, both theoretically implicated in sit-to-stand biomechanics, did

not reach statistical significance for standing-up ability in this cohort. This may reflect the biomechanical threshold effect described above, whereby knee extension becomes the dominant, rate-limiting factor once a critical strength level is reached; the limited statistical power afforded by the small sample size may have further reduced the ability to detect smaller, secondary contributions from these muscle groups.

4.3 Stair-climbing: limited correlations and clinical implications

Regarding stair-climbing ability, no notable correlations with muscle strength emerged. Two factors may explain this. First, stair climbing requires coordinated activation of multiple muscle groups and complex neuromuscular control. Second, the sample distribution was substantially imbalanced, with only two participants completing the task and 16 unable to complete the task. In contrast to walking, stair climbing demands greater range of motion of the lower limb joints, increased muscle activation, and enhanced balance and coordination to move the body forward and upward (30). In patients with IBM, compensatory movement strategies may be used to overcome quadriceps weakness, potentially obscuring direct correlations between individual muscle strength measurements and stair-climbing ability. Stair ascent typically relies on concentric quadriceps contraction to generate vertical propulsion (31). Nonetheless, patients with IBM may adopt alternative strategies in the presence of quadriceps weakness. Furthermore, none of the participants were able to descend stairs without using their upper limbs, highlighting the difficulty of stair descent. This ability relies heavily on eccentric quadriceps control, which appears to be more demanding than stair ascent in patients with IBM (32). The lack of notable correlations between muscle strength and stair-climbing ability requires careful interpretation. This finding should not be interpreted as evidence that muscle strength is unrelated to stair climbing in patients with IBM. Rather, the severely imbalanced sample distribution (only two of 18 participants were able to complete the task) resulted in insufficient statistical power to detect meaningful correlations. The ceiling effect—with 16 participants unable to perform the task—prevented analysis of functional variation among those unable to climb stairs. Therefore, no meaningful conclusions can be drawn from the stair-climbing results, and these findings should be considered preliminary and exploratory. Future studies with larger sample sizes and more balanced functional distributions are needed to clarify the relationships between muscle strength and stair-climbing performance in patients with IBM.

4.4 Rehabilitation strategies and clinical screening implications

Our findings suggest that rehabilitation strategies for patients with IBM should prioritize strengthening the compensatory muscle groups identified in this study. In particular, improving hip flexor, hip extensor, hip abductor,

and knee flexor muscle strength may support gait and help preserve functional independence as the disease progresses. Additionally, strengthening the knee extensors appears essential for maintaining the ability to rise from a seated position. Assistive technologies, including robotic exoskeletons, should be designed to provide targeted support to these key muscle groups, potentially sustaining basic functional abilities. However, owing to limited availability and evidence in the IBM population, such technologies should be framed as future research directions rather than present clinical applications. Rigorous intervention studies with adequate sample sizes and appropriate controls are needed to establish the efficacy, safety, and cost-effectiveness of robot-assisted interventions before clinical implementation.

These findings have important implications for home-based rehabilitation, as many patients with IBM lack access to advanced clinical settings or specialized rehabilitation services. The identification of specific muscle groups that correlate with basic functional abilities may inform simplified, accessible rehabilitation strategies suitable for home-based implementation. Simple resistance exercises targeting these muscles could be performed in the home environment, potentially helping patients preserve functional independence despite progressive muscle weakness. The efficacy of resistance exercise is likely to depend on baseline strength: while patients with mild-to-moderate weakness may derive functional benefit, the effectiveness and safety of resistance training in patients with moderate-to-severe quadriceps weakness remain uncertain and require dedicated study before being recommended for this subgroup. Therefore, future research should develop and validate evidence-based, home-based training protocols targeting these muscle groups in patients with IBM with limited access to clinical services.

4.5 Limitations

This study had several limitations. First, our findings revealed notable correlations between specific muscle strengths and basic functional abilities; however, the results did not establish that training of these muscles directly improves functional outcomes. Therefore, caution is required when interpreting these results, as correlation does not imply causation. Further interventional studies are needed to establish such causal relationships and develop evidence-based rehabilitation protocols for this population. Second, the sample size of 18 participants was relatively small, limiting the generalizability of our findings and reducing statistical power (28). Furthermore, this limited sample size prevented us from performing logistic regression analyses, which would have helped us examine the relative contributions of different muscle groups to functional performance, while controlling for potential confounding variables such as age and disease severity (IBM-FRS score). Consequently, the study could not fully elucidate the complex interrelationships among muscle groups and their combined effect on basic functional abilities and did not determine whether the observed correlations

remain significant after accounting for overall disease severity and demographic factors. Third, our study focused exclusively on muscle strength measurements and did not assess other potential factors that may affect functional performance, such as joint range of motion limitations or balance impairments. These factors could impact basic functional abilities either independently or in combination with muscle weakness in patients with IBM. Fourth, this study categorized functional abilities as binary variables (able vs. unable), which inevitably loses detail about performance quality, speed, or degree of difficulty. Performance scaling measures, such as gait speed in meter per second, sit-to-stand time in seconds, or stair-climbing time, were not collected due to the pilot nature of this study and variability in participant capabilities. Fifth, regarding stair-climbing ability, the severely imbalanced sample distribution (only two of 18 participants completed the task) substantially limited statistical power and the reliability of findings for this functional activity. The lack of notable correlations for stair-climbing should be interpreted with caution, given the significant limitation in sample size and the ceiling effect for inability. Finally, all participants were recruited from a single hospital in Japan, which may limit the generalizability of findings to other geographical regions and healthcare settings. Disease progression, disease severity distribution, rehabilitation practices, and sociodemographic characteristics of patients with IBM in Japan may differ from those in other populations. Additionally, the results may not be applicable to patients with IBM from different ethnic backgrounds or those with different access to rehabilitation services. Sixth, this study did not include an age-matched healthy control cohort, which limits our ability to define normative functional thresholds and to fully contextualize the observed muscle strength values. Seventh, although all six assessors completed a standardization protocol, formal inter-rater reliability was not calculated, and residual inter-rater variability cannot be excluded. Future studies with larger sample sizes and more comprehensive assessment protocols are necessary to address these limitations and better understand the correlation between muscle impairments and functional limitations in this population.

4.6 Conclusion

The study identified potential muscle–function correlations in study participants with IBM. Particularly, moderate correlations emerged between gait ability and the strengths of hip flexion, extension, and abduction and knee flexion. A strong correlation was observed between knee extension strength and the ability to rise from a seated position. Although the CIs were relatively wide, these findings suggest compensatory mechanisms that may help maintain mobility despite disease progression. These insights lay the groundwork for creating more effective clinical assessments and personalized rehabilitation strategies for individuals with IBM. Future rehabilitation efforts should target strengthening these muscles and consider assistive technologies to support

compensatory strategies. However, intervention studies are needed to establish causality.

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The authors have nothing to report.

Ethics Approval Statement

The study was approved by the Ethics Committee (EC) of the National Center of Neurology and Psychiatry (NCNP) Hospital on April 19, 2022 (approval number: A2022-003). This study was conducted in accordance with the principles of the Declaration of Helsinki and its amendments and followed the STROBE reporting guidelines for observational studies.

Patient Consent Statement

Written informed consent was obtained from all participants for study participation and publication of their de-identified data.

Conflicts of Interest Disclosure

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Declaration of generative AI in scientific writing

No single sentence or idea within this manuscript was generated with Claude. We utilized Claude to refine the language in the paper and ensure its style aligns with the standards of a scholarly journal.

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