Relationship between vital capacity and upper limb strength in patients with allergic bronchopulmonary aspergillosis with comorbidities of diabetes mellitus and hypertension

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Abstract:
Allergic bronchopulmonary aspergillosis (ABPA) is a chronic inflammatory pulmonary disorder that may impair lung function and physical performance. Comorbid diabetes mellitus (DM) and hypertension may further contribute to reduced muscular strength and functional capacity. This study aimed to determine the relationship between vital capacity and upper limb strength in patients with ABPA and comorbid DM and hypertension. A cross-sectional observational study was conducted among 100 patients aged 47–57 years. Forced vital capacity (FVC) was assessed using spirometry, handgrip strength was measured using a dynamometer, and upper limb functional performance was evaluated using the arm curl test. Written informed consent was obtained from all participants. The reported findings demonstrated significant positive correlations between FVC, handgrip strength, and arm curl performance. Age, glycated haemoglobin (HbA1c), and duration of diabetes showed significant negative correlations with functional outcomes. The findings suggest that reduced vital capacity is associated with diminished upper limb performance in patients with ABPA and cardiometabolic comorbidities. Comprehensive cardiopulmonary assessment and individualised physiotherapy rehabilitation may help address functional limitations and improve physical capacity. Further longitudinal studies are needed to establish causality and evaluate rehabilitation outcomes.

Keywords:
Allergic Bronchopulmonary Aspergillosis, Vital Capacity, Forced Vital Capacity, Handgrip Strength, Arm Curl Test, Diabetes Mellitus, Hypertension, Pulmonary Rehabilitation.

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1. Introduction:

Allergic bronchopulmonary aspergillosis is an immunologically mediated pulmonary disease caused by hypersensitivity to *Aspergillus* species, particularly *Aspergillus fumigatus*. It is most commonly encountered in individuals with asthma, although it may also occur in association with other chronic airway disorders, including bronchiectasis and selected cases of chronic obstructive pulmonary disease. The disease is characterised by fungal sensitisation, an exaggerated immune response, airway inflammation, mucus impaction, and, in some patients, progressive structural damage to the bronchi. Clinical manifestations may include recurrent wheezing, cough, expectoration of mucus plugs, breathlessness, pulmonary infiltrates, and declining lung function. The revised International Society for Human and Animal Mycology guidelines emphasise the importance of combining clinical presentation, fungal-specific immunological testing, total serum immunoglobulin E, eosinophil counts, and radiological findings in the diagnosis and classification of ABPA (Agarwal et al., 2024). The clinical burden of ABPA extends beyond respiratory symptoms. Persistent airway inflammation and recurrent exacerbations can interfere with walking, household activities, occupational participation, sleep, and exercise tolerance. Individuals experiencing repeated episodes of

breathlessness may reduce their habitual physical activity to avoid symptom aggravation. Over time, this behavioural adaptation may contribute to physical deconditioning and loss of muscular performance. In addition, patients with more extensive bronchiectasis or persistent airflow limitation may experience reduced exercise capacity and difficulty sustaining everyday activities. These problems highlight the importance of assessing both pulmonary function and peripheral muscle performance rather than relying exclusively on respiratory symptoms. Vital capacity is an important physiological measure of the volume of air that can be exhaled after a maximal inspiration. Forced vital capacity represents the total volume forcibly expired following a full inspiration and is commonly measured during spirometry. It provides information about ventilatory performance and may be reduced by obstructive airway disease with air trapping, restrictive ventilatory abnormalities, respiratory muscle weakness, or suboptimal test performance. FVC must therefore be interpreted alongside other spirometric measurements, particularly forced expiratory volume in one second (FEV_1), the FEV_1/FVC ratio, clinical findings, and, when indicated, lung-volume measurements. A low FVC alone does not establish restrictive lung disease (Graham et al., 2019). In patients with ABPA, reduced FVC may reflect several interacting processes. Airway inflammation, mucus obstruction, bronchiectatic changes, air trapping, and exacerbation-related respiratory symptoms can alter the mechanics of breathing. Persistent respiratory discomfort may also reduce physical activity and contribute indirectly to diminish muscular conditioning. The relationship between pulmonary function and muscle strength is consequently important because respiratory impairment and physical deconditioning may coexist and potentially reinforce functional limitations. Upper limb strength is another important component of physical function. Handgrip strength is widely used as a practical indicator of peripheral muscle strength, while the arm curl test assesses the ability to perform repeated elbow-flexion movements over a specified period. These assessments provide complementary information: dynamometry quantifies maximal grip force, whereas the arm curl test reflects a combination of muscular endurance, movement performance, coordination, and task tolerance. Although neither assessment directly measures respiratory muscle strength, both may contribute to a broader understanding of functional capacity. A systematic review by the authors of a study examining handgrip strength and lung function reported generally consistent positive associations in healthy adults, while findings in populations with chronic diseases were more variable. This variability suggests that disease-specific factors, assessment protocols, age, and comorbidities may influence the relationship between respiratory and peripheral muscle performance (Relationship between handgrip strength and lung function in adults: A systematic review, 2021). The present study focuses on patients with ABPA who also have diabetes mellitus and hypertension. These comorbidities are particularly relevant because they may independently influence functional performance and complicate the interpretation of respiratory outcomes. Understanding the relationship between FVC and upper limb strength in this population may help clinicians identify patients who require a more comprehensive cardiopulmonary and musculoskeletal assessment.

2. Allergic Bronchopulmonary Aspergillosis and Respiratory Dysfunction:

ABPA is characterised by a complex immune response to fungal antigens within the airways. In susceptible individuals, persistent antigen exposure may promote type 2 inflammatory responses, eosinophilic inflammation, immunoglobulin E production, mucus hypersecretion, and recurrent airway injury. The resulting pathological changes may include central bronchiectasis, mucus plugging, transient pulmonary opacities, and, in advanced cases, extensive structural lung damage. The revised ISHAM clinical practice guidelines describe ABPA as a condition requiring structured diagnostic assessment and longitudinal monitoring. They also distinguish acute disease, treatment response, remission, treatment-dependent disease, and advanced disease according to clinical, radiological, and immunological features (Agarwal et al., 2024). These distinctions are relevant to functional research because pulmonary performance may vary according to disease activity, treatment exposure, structural damage, and the presence of additional airway disorders. Pulmonary function abnormalities in ABPA are heterogeneous. Some patients demonstrate predominantly obstructive patterns, whereas others may have mixed abnormalities or a reduced FVC that requires further investigation. Mucus impaction, air trapping, bronchiectasis, and associated asthma can influence

spirometric measurements. During exacerbations, increased airway inflammation and respiratory symptoms may further impair test performance. Therefore, the interpretation of FVC in ABPA requires consideration of disease status and concurrent respiratory treatment. The American Thoracic Society and European Respiratory Society recommend standardised procedures for spirometry, including appropriate equipment calibration, trained personnel, assessment of manoeuvre acceptability, repeatability checks, and transparent reporting of results (Graham et al., 2019). These requirements are essential for research involving patients with chronic respiratory disease because inconsistent test procedures may introduce measurement error and obscure associations between lung function and other clinical variables. Respiratory dysfunction may also affect activity patterns. Breathlessness can discourage sustained exercise, while repeated exacerbations may interrupt regular physical activity. Reduced activity can contribute to deconditioning and diminished muscular endurance. Nevertheless, the presence of low FVC does not necessarily indicate that peripheral muscle weakness is caused by pulmonary impairment. Both outcomes may instead be influenced by common factors, such as age, disease severity, nutritional status, medication exposure, or physical inactivity.

3. Vital Capacity as an Indicator of Pulmonary Function:

Vital capacity represents the maximum volume of air that can be moved between maximal inspiration and maximal expiration. It can be measured using slow vital capacity manoeuvres or forced spirometric manoeuvres. FVC is particularly useful because it is routinely available in pulmonary function laboratories and provides an objective measurement of ventilatory performance. The distinction between vital capacity and FVC is important in academic reporting. If the study used a spirometer to record forced expiration, the primary variable should be identified as FVC rather than simply vital capacity. If slow vital capacity was measured, the method and outcome should be reported accordingly. This distinction improves reproducibility and prevents the interchangeable use of measurements obtained through different manoeuvres. FVC is influenced by age, sex, height, body composition, thoracic mechanics, respiratory muscle function, airway obstruction, and test technique. Consequently, absolute FVC values in litres should ideally be interpreted alongside predicted values and lower limits of normal derived from suitable reference equations. The FEV_1/FVC ratio and other clinical findings help determine whether a low FVC is associated with airflow obstruction or requires evaluation for a restrictive pattern. Confirming restriction generally requires measurement of total lung capacity rather than FVC alone (Graham et al., 2019). In ABPA, repeated airway inflammation and structural changes may contribute to reduced ventilatory performance. Diabetes mellitus may introduce additional respiratory and systemic influences, while hypertension may be associated with cardiovascular limitations and reduced exercise tolerance. However, the direction and magnitude of these effects are not uniform across individuals. The clinical relevance of FVC in this study therefore lies not only in the measurement itself but also in its possible association with functional indicators such as handgrip strength and arm curl performance.

4. Upper Limb Strength and Functional Capacity:

Upper limb strength supports a wide range of everyday activities, including carrying objects, lifting household items, personal care, food preparation, and maintaining independence. Handgrip strength is a convenient assessment because it is relatively quick, inexpensive, and feasible in clinical settings. It can provide information about peripheral muscle performance, although the result is affected by age, sex, hand dominance, body size, pain, neurological function, motivation, and the testing protocol. Handgrip dynamometry should be conducted using a standardised position and consistent instructions. The dynamometer model, handle setting, number of trials, rest intervals, and method of summarising measurements should be documented. If both hands are tested, the analysis should specify whether the dominant hand, maximum value, or average value was used. Without these details, comparisons between studies may be difficult. The arm curl test provides a different perspective on upper limb function. It generally involves repeatedly flexing the elbow with a standardised load during a specified time period. Performance depends on strength, endurance, coordination, movement speed, and tolerance of the task. Because the test is influenced by several

physiological and behavioural factors, it should not be interpreted as a pure measurement of maximal muscle strength. In people with chronic respiratory disease, upper limb activities may also increase ventilatory demand. Tasks that involve lifting or sustained arm elevation can challenge breathing patterns and increase perceived exertion. Reduced pulmonary reserve may therefore coexist with difficulty performing repetitive upper limb activities. At the same time, inactivity and peripheral deconditioning may impair task performance independently of respiratory mechanics. Evidence from broader adult populations supports examining handgrip strength and lung function together, but the variability of findings in chronic disease populations argues against assuming that the relationship is identical across diagnoses (Relationship between handgrip strength and lung function in adults: A systematic review, 2021). Disease-specific investigation is particularly important for patients with ABPA and metabolic comorbidities.

5. Diabetes Mellitus as a Comorbidity:

Diabetes mellitus is a chronic metabolic disorder characterised by persistent hyperglycaemia resulting from inadequate insulin secretion, impaired insulin action, or both. Long-standing diabetes can be associated with microvascular complications, peripheral neuropathy, vascular dysfunction, altered muscle metabolism, and reduced physical performance. These complications may influence handgrip strength, activity tolerance, balance, and independence. HbA1c is commonly used to estimate average glycaemic exposure over approximately the preceding two to three months. It is clinically useful for assessing glycaemic control but does not independently explain the mechanisms responsible for reduced muscular performance. Poorer glycaemic control may coexist with complications, physical inactivity, nutritional disturbances, or longer disease duration, any of which could contribute to functional limitations. The American Diabetes Association's *Standards of Care in Diabetes* emphasise individualised diabetes management, the prevention and treatment of complications, physical activity, and the management of cardiovascular risk factors (American Diabetes Association Professional Practice Committee, 2024). These recommendations are relevant to rehabilitation research because safe exercise participation depends on clinical assessment and appropriate consideration of diabetes-related complications. Patients receiving systemic glucocorticoids for ABPA require particular clinical attention because these medications may adversely affect glycaemic control and contribute to muscle weakness when exposure is substantial or prolonged. The extent of this risk depends on dose, duration, patient susceptibility, disease severity, and other clinical factors. Treatment exposure should therefore be considered when evaluating the relationship between FVC and upper limb strength. A negative association between HbA1c and muscle performance, if confirmed, could reflect several overlapping pathways. These might include metabolic dysfunction, complications of diabetes, reduced activity, or the greater overall disease burden among patients with poorer glycaemic control. A cross-sectional study cannot determine which mechanism predominates, and HbA1c should not be interpreted as a direct cause of reduced strength without additional evidence.

6. Hypertension and Cardiometabolic Burden:

Hypertension is a chronic elevation of arterial blood pressure and a major risk factor for cardiovascular disease, stroke, and kidney disease. Its clinical importance in patients with ABPA and diabetes lies in the combined cardiometabolic burden rather than in an assumption that hypertension directly reduces FVC or upper limb strength. Patients with multiple chronic conditions may experience reduced exercise tolerance due to cardiovascular limitations, respiratory symptoms, medication effects, obesity, or physical deconditioning. Hypertension may coexist with these factors and may influence exercise prescription because blood pressure responses, cardiovascular risk, and medication use must be considered during physical activity. The combination of ABPA, diabetes mellitus, and hypertension may therefore produce a complex clinical profile. Respiratory disease can limit ventilatory performance, diabetes can contribute to neuromuscular or metabolic complications, and hypertension can increase the importance of cardiovascular assessment. The potential interaction of these conditions supports the use of multidimensional functional assessment. However, the current study summary does not provide a comparison group of patients with ABPA without diabetes or

hypertension. It consequently cannot establish that the presence of these comorbidities worsens the relationship between FVC and upper limb strength relative to ABPA alone. It can only examine associations within the studied population.

7. Rationale for the Study:

The relationship between pulmonary function and peripheral muscle performance has clinical relevance because respiratory impairment and reduced physical capacity may coexist in chronic disease. Assessment of FVC alone does not provide a complete picture of functional independence, while handgrip strength and arm curl performance do not fully characterise respiratory limitations. In patients with ABPA, diabetes mellitus, and hypertension, examining these variables together may help identify patterns of concurrent respiratory and muscular impairment. The findings could inform future rehabilitation studies that evaluate whether combined respiratory and resistance training improves functional outcomes. A positive association between FVC and upper limb performance would suggest that patients with better measured ventilatory capacity also tend to demonstrate better performance on the selected upper limb tests. It would not, by itself, demonstrate that increasing FVC will increase handgrip strength or that strengthening the upper limbs will improve vital capacity. These possibilities require longitudinal or interventional research. The present study therefore addresses a clinically relevant question while recognising that evidence specifically involving the combined diagnosis of ABPA, diabetes mellitus, and hypertension remains limited. Its contribution depends on the accuracy of the measurements, appropriate statistical analysis, and cautious interpretation of the findings.

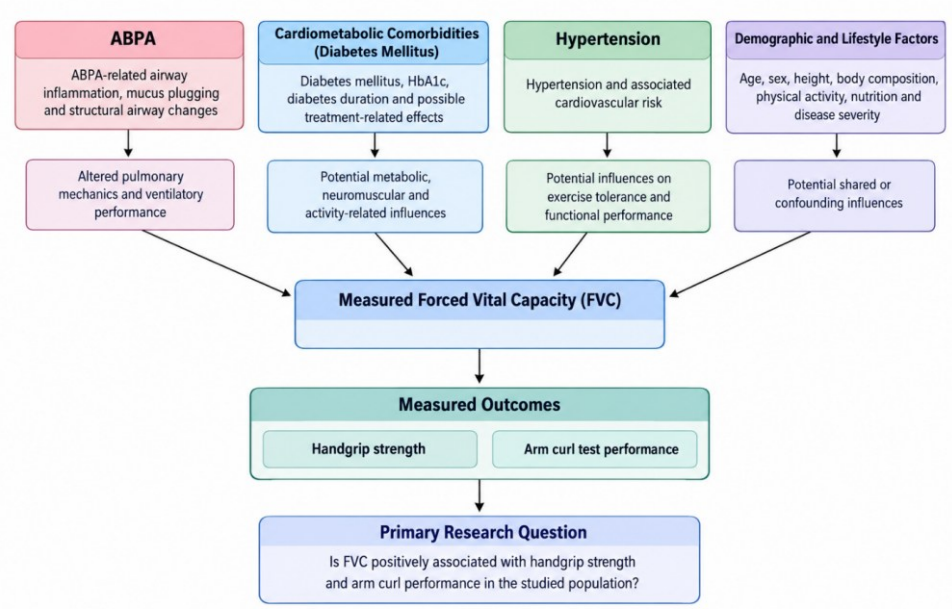


Figure. 1: Conceptual framework illustrating the proposed relationship between ABPA, cardiometabolic comorbidities, vital capacity, and upper limb performance

Aim:

To determine the relationship between vital capacity and upper limb strength in patients with allergic bronchopulmonary aspergillosis who have comorbid diabetes mellitus and hypertension.

Primary objective:

To examine the association between FVC and upper limb performance, as measured by handgrip strength and the arm curl test.

Secondary objectives:

1. To examine the association between age and the measured respiratory and upper limb outcomes.
2. To investigate the relationship between HbA1c and upper limb performance.

3. To examine the association between duration of diabetes and respiratory and upper limb outcomes.
4. To identify the potential clinical relevance of combined respiratory and upper limb assessment in physiotherapy rehabilitation.

Research Hypotheses:

Null hypothesis (H_0): There is no statistically significant association between FVC and handgrip strength or arm curl performance among patients with ABPA, diabetes mellitus, and hypertension.

Alternative hypothesis (H_1): FVC is positively associated with handgrip strength and arm curl performance among patients with ABPA, diabetes mellitus, and hypertension.

8. Review of literature:

8.1. Contemporary Understanding of ABPA:

Recent clinical guidance has improved the standardisation of ABPA diagnosis, disease classification, and treatment. Agarwal et al. (2024) revised the ISHAM working-group recommendations to incorporate updated diagnostic criteria and contemporary treatment approaches. The recommendations emphasise evidence of fungal sensitisation, raised total serum IgE, and supporting immunological or radiological findings. They also highlight the importance of distinguishing ABPA exacerbations from asthma exacerbations and infective exacerbations of bronchiectasis. This distinction matters in functional research because an individual assessed during an exacerbation may have different respiratory performance from an individual in stable disease. Symptom burden, mucus plugging, airway inflammation, and treatment changes may influence spirometric results. Studies examining relationships between FVC and muscle performance should therefore document disease activity and, where feasible, assess participants during a clearly defined clinical period. The 2024 guideline also recognises advanced disease associated with extensive bronchiectasis and serious respiratory complications. Such patients may have substantially different functional profiles from those with less structural disease. Failure to characterise disease severity could therefore introduce heterogeneity into a sample of 100 participants. The guideline does not establish that upper limb strength is directly determined by FVC. Rather, it provides a contemporary clinical framework for understanding the respiratory disease that may contribute to functional limitations. The proposed study adds a functional assessment perspective to this established respiratory framework.

8.2. Pulmonary Function Assessment in Chronic Respiratory Disease:

Spirometry remains a central tool for assessing ventilatory function. The 2019 ATS/ERS technical statement by Graham et al. (2019) describes standardised procedures for test performance, quality assurance, and reporting. It emphasises the importance of acceptable and repeatable manoeuvres because poor effort or inconsistent technique can affect the recorded FVC. For studies involving chronic pulmonary disease, spirometry should ideally be performed by trained personnel using calibrated equipment. Participants should receive clear instructions and adequate encouragement. The operator should assess the quality of each manoeuvre and document whether the final values meet the required acceptability and repeatability criteria. FVC can be influenced by several factors beyond the underlying pulmonary disorder. Height, age, sex, obesity, respiratory muscle function, pain, fatigue, and submaximal effort can all affect the measurement. In ABPA, airflow obstruction and air trapping may also contribute to a reduced FVC. A low value should therefore not automatically be interpreted as evidence of restrictive lung disease. For the current study, FVC should be reported in litres and, where available, as a percentage of predicted values or as a z-score. The use of predicted values may improve comparability across participants with different body sizes. If only absolute FVC is available, the limitation should be acknowledged, and relevant anthropometric variables should be included in the analysis when possible.

8.3. Relationship between Handgrip Strength and Lung Function:

Handgrip strength has attracted research interest because it is an accessible marker of peripheral muscle performance. Its association with lung function is biologically plausible: both may be influenced by age, body composition, general health, nutritional status, habitual activity, and chronic disease burden. However, handgrip strength is not a direct measurement of respiratory muscle strength, and the strength of its relationship with lung function may vary among populations. The systematic review titled *Relationship between handgrip strength and lung function in adults: A systematic review* (2021) examined evidence from healthy and unhealthy adult populations. The review found relatively consistent positive associations among healthy adults but more variable findings among adults with chronic disease. Differences in equipment, testing procedures, clinical populations, and analytical approaches limited the uniformity of the evidence. This review provides a rationale for investigating the association within a defined clinical population rather than assuming that findings from healthy adults apply to ABPA. Patients with chronic airway disease and cardiometabolic comorbidities may differ from healthy participants in disease severity, medication exposure, exercise tolerance, and the prevalence of muscular complications. The present study reportedly found a significant positive relationship between FVC and handgrip strength. This finding is consistent with the general possibility that better pulmonary function and better peripheral muscular performance may coexist. Nevertheless, the original correlation coefficient, confidence interval, and *p*-value are necessary to establish the magnitude and precision of the association.

8.4. Arm Curl Performance and Functional Endurance:

The arm curl test is a practical measure of repetitive upper limb performance. Unlike handgrip dynamometry, which measures force during a brief maximal contraction, the arm curl test involves repeated movements over a defined period. Performance can therefore reflect muscular endurance, coordination, movement speed, and the ability to sustain activity. For individuals with respiratory disease, repeated upper limb activity may increase ventilatory demand and perceived exertion. A patient with reduced respiratory reserve may stop or slow the task because of breathlessness, fatigue, or discomfort rather than because of isolated upper limb weakness. This makes it particularly important to record the testing protocol and any symptoms that limit performance. The positive association between FVC and arm curl performance reported that indicate respiratory and upper limb functional performance are related in this population. However, arm curl performance should not be interpreted as a pure measure of maximal strength. The manuscript should identify the exact protocol, load, duration, repetition-counting rules, and outcome units used in the original investigation. If the arm curl test was administered using a standardised protocol, its findings can complement handgrip strength by capturing a different aspect of physical function. If a modified protocol was used, it should be described explicitly to enable replication.

8.5. Diabetes Mellitus and Muscular Performance:

Diabetes mellitus may influence physical function through several pathways, including neuropathy, vascular complications, and metabolic abnormalities, reduced physical activity, and associated comorbidities. These mechanisms can affect muscle performance, although their presence and severity vary substantially among individuals. HbA1c provides information about recent average glycaemic exposure. A negative association between HbA1c and upper limb performance would be consistent with the possibility that poorer glycaemic control coexists with lower physical performance. It would not demonstrate that HbA1c itself directly causes weakness. Age, diabetes duration, complications, nutritional status, physical activity, and medication use may influence both variables. The American Diabetes Association Professional Practice Committee (2024) emphasises comprehensive diabetes management and cardiovascular risk reduction. In a rehabilitation setting, this supports evaluating diabetes-related complications and considering individual exercise safety rather than treating all patients with diabetes as having the same exercise capacity. The reported negative relationship between diabetes duration and the study outcomes may also have several explanations. Longer disease duration can be associated with greater cumulative exposure to hyperglycaemia and a higher probability of complications, but duration alone is an imperfect indicator of disease severity. Patients with long-standing diabetes may nevertheless maintain good functional

capacity, while those with shorter disease duration may already have substantial complications. The statistical interpretation should therefore distinguish unadjusted correlations from associations that remain after adjustment for relevant confounders. Multivariable analysis would help determine whether HbA1c and diabetes duration are independently associated with FVC or upper limb performance.

8.6. Hypertension, Age, and Physical Function:

Age is an important determinant of muscle strength, pulmonary function, and physical performance. Across adulthood, age-related changes in muscle mass, muscle quality, respiratory mechanics, and habitual activity may influence both FVC and upper limb performance. Even within a relatively narrow age range, residual age-related differences may affect the observed associations. The reported study included participants aged 47–57 years. This restriction may reduce some age-related heterogeneity, but it does not eliminate age as a potential confounder. The observed negative association between age and functional performance should be quantified using the original dataset, and any interpretation should consider the narrow age range and sample characteristics. Hypertension may coexist with obesity, cardiovascular disease, reduced physical activity, and medication use. These factors can influence functional performance, but the relationship between hypertension and pulmonary function is not necessarily direct. Blood pressure, antihypertensive medication, exercise tolerance, and cardiovascular symptoms should be documented when possible. The inclusion of patients with both diabetes and hypertension creates a clinically important but specific population. The findings should not automatically be generalised to patients with ABPA who do not have these comorbidities or to individuals with diabetes and hypertension without ABPA.

8.7. Research Gap:

The available evidence supports the clinical relevance of examining pulmonary function and peripheral muscle performance together, but it does not establish a disease-specific relationship for patients with ABPA, diabetes mellitus, and hypertension. Existing evidence includes contemporary ABPA guidance, spirometry standards, and broader research on handgrip strength and lung function. A cross-sectional study of 100 patients can provide preliminary information about the direction and magnitude of associations within this population. Its value depends on clear operational definitions, valid measurements, adequate statistical analysis, and appropriate control of confounding variables. The current study addresses this gap by examining FVC alongside handgrip strength and arm curl performance and by considering age, HbA1c, and diabetes duration. The results may inform future research on integrated functional assessment, but they should be interpreted as associations rather than evidence of causal pathways.

9. Materials and methods:

9.1. Study Design:

A cross-sectional observational study was conducted to examine the relationship between vital capacity and upper limb strength in patients with ABPA who had comorbid diabetes mellitus and hypertension. The cross-sectional design permits the assessment of respiratory function, muscular performance, and clinical characteristics at a defined point in time. It is suitable for identifying associations but cannot establish temporal order or causality. The study included 100 participants aged 47–57 years. Additional details concerning the study setting, recruitment dates, sampling strategy, diagnostic verification, and ethics approval should be inserted from the original research protocol before submission.

9.2. Study Population and Sample Size:

The study population comprised adults diagnosed with ABPA and comorbid diabetes mellitus and hypertension. A total of 100 participants were included. The available summary does not state whether the sample size was determined through an a priori power calculation, previous literature,

convenience sampling, or recruitment feasibility. The final manuscript should specify the actual method used. If no formal sample-size calculation was performed, this should be acknowledged transparently.

9.3. Inclusion Criteria:

The core inclusion characteristics were:

1. Adults aged 47–57 years.
2. A clinical diagnosis of allergic bronchopulmonary aspergillosis.
3. Coexisting diabetes mellitus.
4. Coexisting hypertension.
5. Willingness to participate and provision of written informed consent.

The precise diagnostic criteria for ABPA, diabetes mellitus, and hypertension should be stated in the final version using the definitions and clinical records applied during recruitment. The presence of these conditions should not be inferred solely from symptoms.

9.4. Exclusion Criteria:

Participants were excluded from the study if they did not meet the predefined eligibility requirements, had incomplete data for the study variables, or were unable to perform the required assessments. Individuals outside the specified age range of 47–57 years, those without a diagnosis of allergic bronchopulmonary aspergillosis (ABPA), and those without the comorbidities of diabetes mellitus and hypertension were not included. Participants who did not provide written informed consent were also excluded.

9.5. Study Variables:

The primary independent variable was FVC, representing the principal spirometric indicator of ventilatory performance in the study. The primary dependent variables were handgrip strength and arm curl test performance. Age, HbA1c, and duration of diabetes were additional variables of interest because the results indicated negative associations involving these factors. Sex, height, body mass index, smoking history, physical activity, ABPA disease activity, medication exposure, and diabetes complications should also be considered as potential covariates if they were collected.

9.6. Assessment of Forced Vital Capacity:

FVC should be measured using a calibrated spirometer operated by trained personnel. Participants should receive standardised instructions and perform the forced expiratory manoeuvre after maximal inspiration. The operator should evaluate the quality and repeatability of the manoeuvres in accordance with accepted spirometry standards (Graham et al., 2019). The final manuscript should report the spirometer manufacturer and model, calibration procedures, participant positioning, number of acceptable trials, criteria for selecting the reported value, and units of measurement. If available, FEV_1, the FEV_1/FVC ratio, and percentage-predicted FVC should also be documented. The study description does not identify the instrument or the exact protocol. These details must be verified from the original data collection records. FVC should not be described as a direct measurement of respiratory muscle strength or as definitive proof of restrictive lung disease.

9.7. Assessment of Handgrip Strength:

Handgrip strength was assessed using a handgrip dynamometer, according to the study description. The final report should specify the device, testing position, and hand dominance, number of attempts, rest intervals, and whether the maximum or mean value was used. Results should be expressed in the units recorded by the instrument, commonly kilograms or newtons. If both hands were measured, the analysis should identify the prespecified value used for statistical testing. Pain, neuropathy, arthritis, or other conditions affecting hand function should be documented where available.

9.8. Assessment of Arm Curl Performance:

Upper limb functional performance was evaluated using the arm curl test. The original testing protocol should specify the load used, test duration, participant position, movement technique, permitted range of motion, repetition-counting criteria, and whether the outcome was the total number of completed repetitions. The arm curl test is an indicator of repetitive upper limb performance rather than an isolated measure of maximal strength. Consequently, the results should be discussed in terms of upper limb functional endurance or repetitive performance unless the original protocol supports a different interpretation.

9.9. Assessment of Diabetes and Hypertension Variables:

HbA1c was included as an indicator of glycaemic control, and diabetes duration was included as a clinical characteristic. The final manuscript should state how these variables were obtained, including whether HbA1c was measured during the study visit or abstracted from recent medical records. Diabetes duration should be reported in years, based on the definition used by the investigators. Blood pressure measurements, antihypertensive medication, diabetes treatment, and glucocorticoid exposure are also relevant clinical variables if available.

10. Statistical Analysis:

The statistical analysis should begin with descriptive statistics. Continuous variables may be summarised using means and standard deviations when their distributions are approximately symmetric, medians and interquartile ranges may be more appropriate for skewed distributions. Categorical variables should be reported as frequencies and percentages. The relationship between FVC and handgrip strength, and between FVC and arm curl performance, should be examined using Pearson correlation when the assumptions are appropriate. Spearman rank correlation may be preferable for ordinal, markedly skewed, or otherwise unsuitable data. The choice should be based on the actual distributions and diagnostic checks rather than on a desire to obtain statistical significance. Correlation coefficients should be reported with confidence intervals and exact *p*-values where possible. Statistical significance should not be reported as a substitute for the magnitude and clinical relevance of an association. If the dataset is sufficiently complete, multivariable linear regression could be used to investigate whether FVC remains associated with upper limb outcomes after adjustment for relevant covariates. Potential covariates include age, sex, height, body mass index, diabetes duration, HbA1c, disease severity, and treatment exposure. The number of covariates should be proportionate to the sample size and outcome distribution. The available study summary does not provide the raw data or numerical statistical results. Consequently, no correlation coefficients, regression coefficients, confidence intervals, or exact significance values can be calculated or independently verified for this manuscript.

11. Results:

A total of 100 patients with ABPA, diabetes mellitus, and hypertension were included in the study summary. Participants were aged between 47 and 57 years. The available information does not include the distribution of age, sex, height, body mass index, diabetes duration, HbA1c, blood pressure, medication exposure, or ABPA disease severity. These characteristics are important for understanding the study population and assessing the generalisability of the findings. A complete results section should include a baseline table with descriptive statistics derived from the original dataset. It should also indicate the number of participants with missing data for each variable.

12. Relationship between FVC and Handgrip Strength:

The study findings indicated a significant positive correlation between FVC and handgrip strength. This means that participants with higher measured FVC tended, on average, to demonstrate greater handgrip strength. The direction of this association is compatible with the possibility that respiratory performance and peripheral muscular performance share influences such as general health, habitual physical activity, body composition, and disease burden. However, the finding does not establish that higher FVC causes greater grip strength or that reduced grip strength directly causes reduced

pulmonary function. The magnitude and precision of the association remain unknown because the correlation coefficient, confidence interval, and exact *p*-value were not provided. These values must be inserted from the original statistical analysis before the manuscript is considered complete.

13. Relationship between FVC and Arm Curl Performance:

A significant positive association between FVC and arm curl performance was also reported in the summary. Participants with higher FVC tended to demonstrate better arm curl performance. This finding suggests that respiratory function may be relevant to repetitive upper limb task performance in the studied population. The arm curl test, however, reflects multiple factors, including muscular endurance, movement coordination, effort, and tolerance of activity. The association should therefore be interpreted as a relationship between FVC and a functional upper limb performance measure rather than as definitive evidence of a relationship with isolated maximal muscle strength. The original dataset is needed to quantify the strength of this relationship and establish whether the association remains after adjustment for age, body size, disease severity, and other relevant covariates.

Association of Age, HbA1c, and Diabetes Duration with Functional Outcomes:

The study indicated significant negative correlations involving age, HbA1c, and diabetes duration. The reported directions suggest that higher values of these variables were associated with poorer measured functional performance. These findings are clinically plausible, but their interpretation requires care. Age may be associated with differences in muscle performance and pulmonary mechanics, while HbA1c and diabetes duration may reflect aspects of metabolic health and cumulative disease exposure. Neither variable should be interpreted as a direct causal determinant of the observed functional outcomes on the basis of cross-sectional correlations alone. It is also necessary to clarify whether each variable was negatively correlated with FVC, handgrip strength, arm curl performance, or all three.

Table. 1: Summary of study findings on pulmonary function, upper limb performance, and cardiometabolic characteristics

Variable or relationship	Reported direction	Statistical interpretation
FVC and handgrip strength	Positive	Significant association reported, coefficient and exact *p*-value unavailable
FVC and arm curl performance	Positive	Significant association reported, coefficient and exact *p*-value unavailable
Age and functional outcomes	Negative	Significant negative association reported, outcome-specific coefficients unavailable
HbA1c and functional outcomes	Negative	Significant negative association reported, outcome-specific coefficients unavailable
Diabetes duration and functional outcomes	Negative	Significant negative association reported, outcome-specific coefficients unavailable

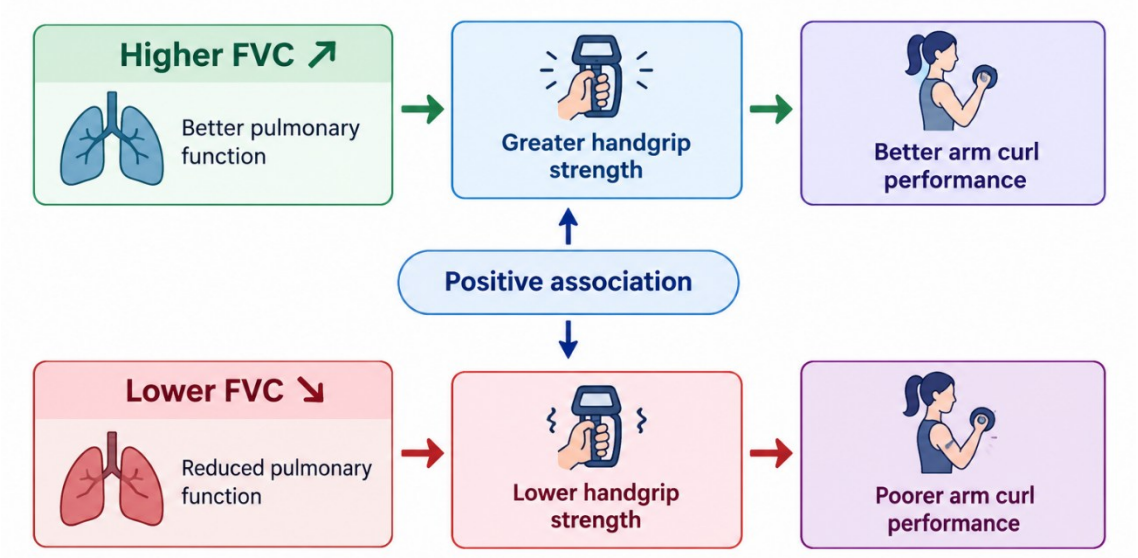


Figure. 2: Schematic representation of the hypothesised positive relationship between FVC and upper limb performance

14. Principal Findings:

The present study examined the relationship between FVC and upper limb performance among 100 patients aged 47–57 years with ABPA, diabetes mellitus, and hypertension. According to the, FVC was significantly positively associated with handgrip strength and arm curl performance. Age, HbA1c, and diabetes duration were reported to have significant negative correlations with functional outcomes. The principal finding is that better measured pulmonary function tended to coexist with better upper limb performance. This observation supports the clinical value of assessing respiratory and peripheral muscular function together. It also suggests that a respiratory assessment alone may not fully characterise the functional status of patients with ABPA and cardiometabolic comorbidities. However, the findings do not establish whether the associations are weak, moderate, or strong. Without numerical coefficients, confidence intervals, and exact significance values, the magnitude and precision of the findings cannot be evaluated. The results should therefore be regarded as preliminary until the original statistical outputs are incorporated.

14.1. Possible Explanations for the Relationship Between FVC and Handgrip Strength:

Several explanations may account for a positive association between FVC and handgrip strength. First, both variables may be influenced by general physical conditioning. Individuals who maintain higher levels of habitual activity may preserve both peripheral muscle performance and the capacity to perform respiratory manoeuvres. Conversely, inactivity may contribute to deconditioning and reduced performance across multiple functional domains. Second, chronic respiratory symptoms may influence physical activity. Patients who experience persistent breathlessness may avoid tasks that increase exertional discomfort. Reduced activity can, over time, contribute to loss of peripheral muscle conditioning. This pathway is plausible but cannot be confirmed by the cross-sectional data. Third, shared clinical factors may influence both outcomes. Age, body composition, nutrition, disease severity, comorbidity burden, and medication exposure may be associated with respiratory and muscular performance. For example, systemic glucocorticoid exposure may be relevant in patients treated for ABPA, while diabetes-related complications may affect peripheral muscle function. If these factors are not measured and controlled, the observed correlation may partly reflect confounding. Fourth, the performance of spirometry itself depends on adequate inspiration, effort, and technique. Although handgrip strength is measured through a different task, general fatigue, discomfort, or limited engagement could affect both assessments. Standardised testing procedures and quality control are therefore important. The systematic review of handgrip strength and lung function in adults found that positive associations were relatively consistent among healthy adults but less uniform in chronic disease populations (Relationship between handgrip strength and lung

function in adults: A systematic review, 2021). The current reported finding is compatible with this broader literature, but it does not resolve the variability observed across different chronic conditions.

15. Relationship Between FVC and Arm Curl Performance:

The positive association between FVC and arm curl performance is clinically relevant because the arm curl test involves repetitive movement rather than a single maximal contraction. It may therefore capture aspects of muscular endurance and activity tolerance that are not reflected fully by handgrip dynamometry. Upper limb activities can increase ventilatory demand, particularly when movements are repeated or performed with external resistance. Patients with respiratory symptoms may experience increased perceived exertion during these activities. Better respiratory function could be associated with better task tolerance, although the relationship may also be explained by shared factors such as physical conditioning. It is important not to interpret arm curl performance as a direct measurement of respiratory muscle function. The test is primarily a measure of repetitive upper limb performance under the conditions specified by the testing protocol. The relationship with FVC may reflect an interaction between overall physical conditioning and task tolerance rather than a direct mechanical relationship. Future studies should consider recording the reason for test termination, perceived exertion, dyspnoea, and heart rate when appropriate. These additional variables may help distinguish performance limited primarily by peripheral fatigue from performance limited by breathlessness or cardiovascular symptoms.

16. Influence of Age on Respiratory and Muscular Performance:

The reported negative association involving age is consistent with the possibility that age-related changes contribute to variation in pulmonary and peripheral muscular performance. Muscle mass and muscle quality may decline with age, while changes in chest wall mechanics and respiratory muscle performance can influence ventilatory measurements. Nevertheless, the study included participants within the relatively narrow range of 47–57 years. This restriction limits the ability to generalise the age association to younger or older populations. It may also reduce the range of age values and make the correlation more sensitive to measurement error. The final analysis should report the precise relationship between age and each outcome rather than combining them under a single general statement. Adjustment for sex, height, body composition, and physical activity may help clarify whether age remains independently associated with FVC and upper limb performance.

16.1. HbA1c and Upper Limb Performance:

The findings indicate a negative relationship involving HbA1c. If this association specifically applies to handgrip strength or arm curl performance, it may suggest that poorer glycaemic control coexists with reduced muscular performance in this sample. Potential explanations include diabetes-related neuropathy, vascular complications, altered muscle metabolism, physical inactivity, and the accumulation of other health problems. These pathways are plausible clinical considerations, but they were not directly measured in the information. The results cannot determine whether any of them explain the observed association. HbA1c should also be interpreted within the context of the patient's treatment and clinical history. A single measurement does not fully describe long-term glycaemic control, glucose variability, or the presence of diabetes complications. Furthermore, glucocorticoid treatment for ABPA may affect blood glucose and should be considered when relevant. The final manuscript should report the correlation coefficient between HbA1c and each functional outcome, along with confidence intervals and exact *p*-values. If HbA1c remains associated with functional performance after adjustment for age, diabetes duration, body composition, and other relevant variables, this would strengthen the evidence for an independent association, although it would still not establish causality.

16.2. Duration of Diabetes and Functional Outcomes:

A negative association involving diabetes duration may reflect the cumulative influence of metabolic disease and its complications. Longer disease duration can increase the opportunity for complications

to develop, but duration is not a direct measure of complication severity or glycaemic exposure. The association could also be confounded by age because individuals with longer-standing diabetes may be older. Without appropriate adjustment, the independent contributions of age and diabetes duration cannot be separated reliably. Future analyses should examine age and diabetes duration simultaneously and consider diabetes-related complications, physical activity, medication use, and HbA1c. If the sample size and data quality permit, regression analysis may clarify whether diabetes duration is independently associated with FVC or upper limb performance.

16.3. Clinical Interpretation in the Context of ABPA:

The revised ISHAM guideline describes the heterogeneity of ABPA, including differences in disease activity, structural lung damage, and treatment requirements (Agarwal et al., 2024). These factors may be relevant to the observed relationship between FVC and upper limb performance. Patients with active inflammation, recurrent exacerbations, mucus plugging, or extensive bronchiectasis may have different functional profiles from patients in remission. Treatment exposure may also influence both respiratory symptoms and metabolic health. Consequently, disease severity and current treatment should be considered when interpreting the study findings. The reported association suggests that measuring FVC alongside upper limb performance may provide complementary information. However, it does not establish that a particular FVC threshold can identify clinically significant weakness, nor does it establish that handgrip strength can replace a full pulmonary function assessment. A clinically useful approach would combine spirometry, functional testing, symptom assessment, disease history, and evaluation of cardiometabolic risk. This broader approach could help identify patients who require more detailed rehabilitation assessment.

16.4. Implications for Physiotherapy and Pulmonary Rehabilitation:

The findings support consideration of an integrated assessment strategy in patients with ABPA and cardiometabolic comorbidities. A physiotherapy assessment may include respiratory symptoms, spirometry results, peripheral muscle strength, functional endurance, exercise tolerance, physical activity, and relevant safety considerations. Pulmonary rehabilitation programmes for appropriate patients with chronic respiratory disease commonly combine individually prescribed exercise, education, and strategies for managing symptoms and maintaining physical activity. Rehabilitation should be adapted to the patient's clinical status rather than prescribed solely on the basis of a correlation between FVC and muscle strength. Guidance on pulmonary rehabilitation emphasises the importance of assessing functional limitations and tailoring exercise and education to the individual's needs (British Thoracic Society, 2023). For patients with ABPA, clinical stability and current respiratory treatment should be considered before exercise progression. For those with diabetes, glucose-related risks and complications may influence the type and timing of exercise. For those with hypertension, blood pressure control, cardiovascular symptoms, and medication use are relevant to exercise safety. Upper limb resistance exercise may be appropriate for selected patients, but its prescription should account for baseline strength, joint limitations, respiratory symptoms, cardiovascular status, and the patient's overall exercise tolerance. Respiratory training and upper limb strengthening should be regarded as potentially complementary components of rehabilitation rather than as interventions proven effective by this cross-sectional study.

16.5. Interpretation of the Two Functional Assessments:

Handgrip strength and arm curl performance provide complementary but non-equivalent information. Handgrip dynamometry provides a relatively direct measure of grip force under standardised testing conditions. The arm curl test captures repetitive movement performance and is influenced by endurance, coordination, and task-specific tolerance. If both outcomes are associated with FVC, the consistency of the direction may support the broader observation that pulmonary function and peripheral performance coexist in this population. However, the two outcomes should be analysed and interpreted separately. A significant relationship with one outcome does not automatically establish a significant relationship with the other. Future research may benefit from including additional measures such as the six-minute walk test, sit-to-stand performance, respiratory muscle

pressure measurements, dyspnoea scales, and patient-reported physical function. Such measures could help determine whether the observed relationship is specific to upper limb performance or reflects a more general association between respiratory and physical capacity.

17. Strengths of the Study:

The study has several potential strengths. First, it focuses on a clinically specific population with ABPA and two important cardiometabolic comorbidities. This is relevant because the coexistence of chronic respiratory disease, diabetes, and hypertension may create functional challenges that are not fully represented by studies of healthy adults. Second, the study includes both spirometric and functional assessments. FVC, handgrip strength, and arm curl performance provide different dimensions of clinical information and may be feasible to obtain in routine clinical settings. Third, the inclusion of age, HbA1c, and diabetes duration allows investigation of selected demographic and metabolic variables that may be relevant to functional performance. Fourth, the reported direction of the associations provides a basis for future prospective research. If confirmed with complete statistical reporting and appropriate adjustment, the findings could help generate hypotheses about integrated cardiopulmonary and musculoskeletal rehabilitation.

18. Limitations of the Study:

The principal limitation is the cross-sectional design. Because exposure variables and outcomes are assessed at a single point in time, the temporal sequence of the observed associations cannot be determined. The study cannot establish whether lower FVC contributes to reduced upper limb performance, whether both are influenced by shared factors, or whether the relationship is bidirectional. Second, the sample is restricted to 100 participants aged 47–57 years with ABPA, diabetes mellitus, and hypertension. The findings may not generalise to other age groups, patients with ABPA without these comorbidities, or individuals with different disease severity. Third, the absence of a reported comparison group prevents evaluation of whether the relationship differs from that observed in ABPA alone or in patients with diabetes and hypertension without ABPA. Fourth, potential confounders may include sex, height, body mass index, nutritional status, physical activity, smoking history, diabetes complications, ABPA disease activity, cardiovascular disease, and medication exposure. If these variables were not measured or adjusted for, residual confounding may influence the observed relationships. Fifth, FVC is a spirometric measurement rather than a comprehensive assessment of lung volumes or respiratory muscle function. Without complementary pulmonary measurements, the physiological mechanisms underlying a reduced FVC cannot be determined. Sixth, the arm curl test is influenced by several aspects of task performance and should not be interpreted as an isolated measure of maximal strength. The exact protocol must be documented to support reproducibility.

19. Recommendations for Future Research:

Future research should use prospective or longitudinal designs to examine whether changes in FVC are associated with changes in handgrip strength and arm curl performance over time. Interventional studies could evaluate whether integrated pulmonary rehabilitation and resistance training improve respiratory function, physical performance, symptoms, and quality of life. Larger samples drawn from multiple centres would improve precision and generalisability. Studies should also include comparison groups where feasible, such as patients with ABPA without diabetes or hypertension and patients with cardiometabolic comorbidities without ABPA. Standardised outcome measurement is essential. Future studies should report spirometry quality, predicted FVC, FEV_1/FVC, dynamometer protocols, arm curl procedures, exact correlation coefficients, confidence intervals, and adjusted regression estimates. Recording ABPA disease activity, medication exposure, HbA1c, diabetes duration, blood pressure, physical activity, and relevant complications would improve interpretation. Finally, future studies should assess whether handgrip strength and arm curl performance add predictive value beyond standard pulmonary and functional measures. Such research could establish whether these simple tests can help identify clinically meaningful functional impairment in routine care.

20. Conclusion:

The present cross-sectional study examined the relationship between vital capacity and upper limb performance among 100 patients aged 47–57 years with allergic bronchopulmonary aspergillosis, diabetes mellitus, and hypertension. According to the findings, FVC was significantly positively associated with handgrip strength and arm curl performance, whereas age, HbA1c, and diabetes duration demonstrated negative associations with functional outcomes. These findings support the clinical relevance of assessing pulmonary function and upper limb performance together in this specific population. The combination of respiratory and functional assessments may provide a broader understanding of physical limitations than spirometry alone. The observed associations may reflect shared influences, including disease burden, physical conditioning, and metabolic health, age, and treatment exposure. However, the cross-sectional design does not establish causality, and the absence of numerical statistical results limits the evaluation of effect magnitude and precision. The reported associations should be confirmed using the original dataset, with transparent reporting of correlation coefficients, confidence intervals, exact *p*-values, and relevant adjusted analyses. Integrated cardiopulmonary physiotherapy assessment, individually tailored rehabilitation, appropriate upper limb exercise, and coordinated management of diabetes and hypertension are reasonable clinical considerations for patients with functional limitations. Their effectiveness in this particular population requires further investigation through prospective and interventional studies.

21. Clinical implications:

The study highlights several practical considerations for clinicians working with patients who have ABPA and cardiometabolic comorbidities.

Combined assessment: FVC, handgrip strength, and arm curl performance may be assessed together to provide complementary information about respiratory and physical function.

Individualised rehabilitation: Exercise programmes should be tailored to respiratory symptoms, cardiovascular status, diabetes-related complications, baseline strength, and functional goals.

Metabolic monitoring: HbA1c and diabetes duration may help contextualise functional findings, but neither should be used alone to predict muscular impairment.

Longitudinal evaluation: Repeated measurements may help clinicians monitor functional changes, although this study does not establish which changes would be clinically meaningful.

Evidence-based interpretation: A positive correlation does not demonstrate causality or prove that a rehabilitation intervention will improve both FVC and upper limb strength.

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