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Mobility-Related Disability, Body Mass Index, and Cardiometabolic Disease Among Adults in Puducherry, India: A Cross-Sectional Mediation Analysis

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Abstract

Background

Mobility-related disability and cardiometabolic disease frequently coexist, but the contribution of adiposity to this association remains uncertain. We examined the association between mobility-related disability and hypertension and/or diabetes, with body mass index (BMI) as a potential mediator, among adults in Puducherry, India.

Materials and methods

This community-based cross-sectional study included 1,376 adults recruited from 18 wards/villages using multistage cluster sampling. Mobility-related disability was defined as any self-reported difficulty in the mobility domain of the World Health Organization rapid Assistive Technology Assessment tool. BMI was modeled continuously, and the primary outcome was hypertension and/or diabetes. Adjusted linear and logistic regression models included prespecified demographic, socioeconomic, behavioral, and family-history covariates. Indirect effects were estimated within a counterfactual framework using ward-level clustering and 5,000 quasi-Bayesian simulations. Small-cluster sensitivity analyses included CR2-adjusted regression inference and a 999-replicate ward-level bootstrap.

Results

Mobility-related disability was reported by 144 participants (10.5%), and 586 (42.6%) had the composite cardiometabolic outcome. Mobility-related disability was associated with a higher BMI (adjusted $\beta = 2.36$ kg/m²; 95% CI: 1.04-3.68). Each 1 kg/m² increase in BMI was associated with 1.08 times the adjusted odds of cardiometabolic disease (95% CI: 1.05-1.11). The average causal mediation effect (ACME) through BMI corresponded to a significant 3.8-percentage-point difference in the predicted probability of cardiometabolic disease (ACME = 0.038; 95% CI: 0.015-0.067). The indirect estimate remained positive in all 18 leave-one-cluster-out analyses and in the ward-level bootstrap (95% CI: 0.020-0.058).

Conclusions

BMI showed a positive statistical indirect association between mobility-related disability and cardiometabolic disease, supporting consideration of adiposity as a potentially modifiable factor in disability-inclusive cardiometabolic risk assessment. Further evaluation is needed for accessible nutrition, weight management, physical activity, and screening approaches. However, the cross-sectional nature of the study prevents the establishment of a causal pathway.

Categories: Preventive Medicine, Epidemiology/Public Health, Endocrinology/Diabetes/Metabolism
Keywords: body mass index, cardiometabolic disease, disability-inclusive prevention, india, mediation analysis, mobility disability, noncommunicable diseases

Introduction

Disability is a major global public health and health-equity issue. The World Health Organization estimates that approximately 1.3 billion people, or 16% of the global population, live with significant disability [1]. In India, Census 2011 reported 26.8 million persons with disabilities, representing 2.21% of the population [2]. Mobility limitations are particularly relevant to prevention because they can restrict everyday movement and participation and may make conventional health-promotion approaches less accessible.

India carries a substantial burden of cardiometabolic noncommunicable disease (NCD). The ICMR-INDIAB

national study estimated the weighted prevalence of diabetes and hypertension at 11.4% and 35.5%, respectively [3]. Population-based evidence from Korea has shown a higher prevalence and risk of type 2 diabetes among adults with disabilities than among adults without disabilities [4]. At the same time, people living with disabilities are less likely to participate in recommended levels of physical activity [5], and disability-associated low energy expenditure and deconditioning may contribute to adverse metabolic profiles [6].

Body mass index (BMI) is therefore a plausible marker connecting mobility-related functional limitation with cardiometabolic disease. However, the relationship is potentially bidirectional. Longitudinal evidence indicates that higher body weight can precede mobility-related disability and that established mobility-related disability can also be followed by weight gain [7]. This issue is especially relevant in South Asian populations, in whom cardiometabolic risk may occur at lower BMI levels than in many Western populations [8,9].

Previous research examining disability and chronic disease has combined different disability domains, described disability-related cardiometabolic risk, or included BMI as an adjustment variable without examining its potential mediating role in the association between mobility-specific limitations and cardiometabolic disease. Assessing an indirect association through continuously measured BMI may help distinguish the observed mobility-BMI and BMI-disease relationships within a single conceptual framework. We therefore examined the statistical indirect association of mobility-related disability with hypertension and/or diabetes through BMI among adults in Puducherry, India, accounting for the clustered sampling design. Given the cross-sectional measurements, this study did not seek to establish temporal or causal mediation.

Materials And Methods

Study design and setting

A community-based cross-sectional survey was conducted in Puducherry, a Union Territory on the southeastern coast of India, from February 2024 to August 2025 as part of an Indian Council of Medical Research-funded multicentric project using the World Health Organization rapid Assistive Technology Assessment (rATA) tool. The multicentric study was conducted to assess assistive technology needs, use, and access, as well as unmet needs, across participating centers and age groups. This study is a planned secondary analysis of the Puducherry center, restricted to adults aged 18 years or older and focused on mobility-related disability, measured BMI, and cardiometabolic disease. The analytic population, outcomes, and mediation-based statistical approach were defined according to the research question developed during study planning, and the corresponding measurements were collected as part of the parent survey.

Sampling and participants

Multistage cluster sampling was conducted using the current list of administrative regions in Puducherry as the sampling frame. One rural and one urban block were selected through stratified random sampling, followed by selection of wards/villages using probability proportional to size. The 18 selected wards/villages constituted the sampling clusters. Within each cluster, one street was chosen at random. A die roll identified the starting household among the first six households on that street, after which every second household was selected. All available, eligible residents aged 18 years or older in the selected households were approached; those acutely ill or unavailable at the time of survey were excluded before approach. Interviews and measurements were completed by trained field personnel using standardized procedures.

Exposure and mediator

Mobility-related disability was assessed using the rATA mobility item [10]. The instrument was translated into Tamil, back-translated, pretested, and pilot-tested in two separate wards of Puducherry before interviewer-administered assessment based on participant self-report. The item assessed difficulty in sitting, standing, walking, or climbing steps without support or equipment, with response categories of no difficulty, some difficulty, a lot of difficulty, or inability to do so. For the primary analysis, any difficulty (some difficulty or greater) was classified as mobility-related disability; the full severity distribution was also described. Formal psychometric validation of the translated item was not undertaken in this study.

During household visits, weight was measured using a digital weighing scale while participants wore light clothing and no footwear. Height was measured using a non-stretchable measuring tape according to standard measurement guidelines. BMI was calculated as weight in kilograms divided by height in meters squared and was retained as a continuous mediator to avoid information loss from categorization.

Cardiometabolic outcomes

Blood pressure was measured using an automated monitor (OMRON Healthcare Co., Ltd., Kyoto, Japan) in the seated position, with adequate rest, back support, and uncrossed legs. If the initial reading was elevated, a second measurement was obtained after approximately 30 minutes of rest to reduce possible transient influences, and the second reading was used for classification. Hypertension was defined as systolic blood

pressure ⩾140 mmHg, diastolic blood pressure ⩾90 mmHg, or previously diagnosed hypertension, including treated individuals with controlled measurements.

Random blood glucose was measured using a OneTouch glucometer (LifeScan, Malvern, PA, USA), and a random glucose >200 mg/dL triggered a confirmatory fasting assessment. Diabetes was defined using fasting blood glucose ⩾126 mg/dL or a prior diagnosis, including treated individuals with controlled glucose levels. The primary cardiometabolic outcome was hypertension and/or diabetes, derived from these component indicators. All equipment used in the study was calibrated according to the manufacturer's guidance.

Covariates

Prespecified adjustment variables were age, sex, socioeconomic status, marital status, inadequate fruit and vegetable intake, current tobacco use, current alcohol use, family history of diabetes, and family history of hypertension. Socioeconomic status was classified using the modified B. G. Prasad scale for 2025 [11]. Fruit and vegetable consumption was assessed by weekly dietary recall, with fewer than five servings per week classified as inadequate. Tobacco and alcohol histories were elicited using current-use, ever-use, and never-use response options; current use was included in adjusted models. Physical activity was assessed from self-reported weekly duration, with fewer than 150 minutes per week classified as inadequate. Physical inactivity was reported descriptively but was not treated as a baseline confounder because it could be downstream of mobility limitation and upstream of BMI.

Mediation framework

The prespecified conceptual model was built with mobility-related disability as the exposure, BMI as the potential mediator, and cardiometabolic disease as the outcome, with an indirect mobility-BMI-disease association and a possible pathway that does not operate through BMI. Covariate selection was guided by an a priori directed acyclic graph. Counterfactual mediation analysis was used to estimate the average causal mediation effect (ACME), average direct effect (ADE), total effect, and proportion mediated [12-14]. Because all three variables were assessed cross-sectionally, their temporal ordering could not be established. Therefore, the estimates were interpreted as model-based statistical indirect associations under the hypothesized ordering rather than as evidence of a causal pathway [15]. Figure *1* shows the hypothesized conceptual structure.

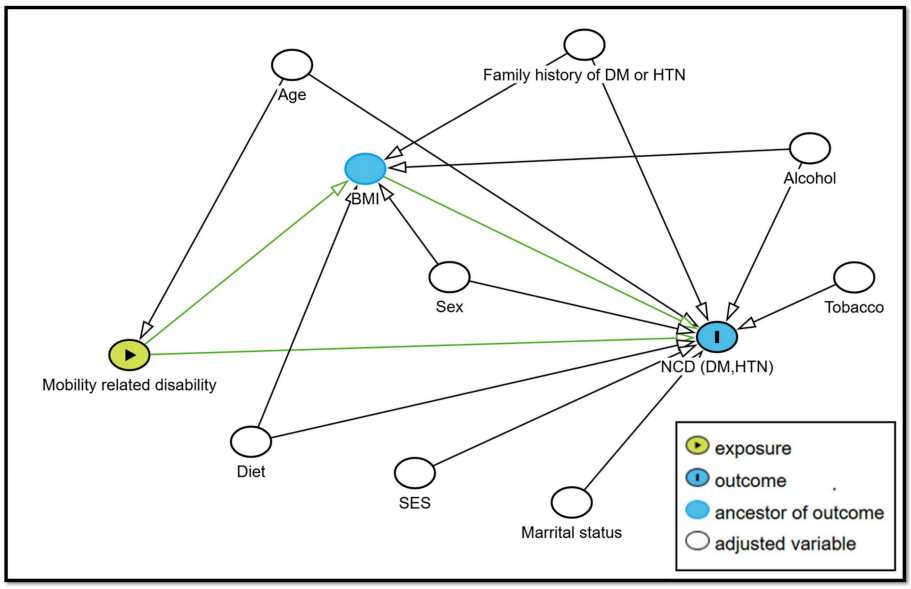


FIGURE 1: Hypothesized causal pathways linking mobility-related disability, BMI, and cardiometabolic disease

The directed acyclic graph depicts hypothesized relationships between mobility-related disability (exposure), BMI (potential mediator), and cardiometabolic disease (diabetes and/or hypertension). Green arrows indicate the principal exposure-mediator, mediator-outcome, and exposure-outcome pathways; black arrows indicate hypothesized relationships involving the measured adjustment variables. The yellow-green node denotes the exposure, the blue node the outcome, the light-blue node an ancestor of the outcome, and white nodes adjusted variables.

DM: diabetes mellitus, HTN: hypertension, SES: socioeconomic status, BMI: body mass index, NCD: noncommunicable disease

The figure was created by the authors using DAGitty (https://dagitty.net, Germany)

Sample size

The separate study-specific sample size was calculated assuming cardiometabolic disease prevalences of 40% among adults without mobility-related disability and 50% among those with mobility-related disability, 95% confidence, 80% power, a planning design effect of 1.5, an average cluster size of 40, and 10% nonresponse, yielding a minimum target sample size of 1,290. The calculation was intended for the principal cardiometabolic comparison rather than to ensure precision for mediation effects or severity-defined subgroups.

Statistical analysis

Continuous variables were summarized as means and standard deviations, and categorical variables as counts and percentages. A descriptive comparison by mobility-difficulty status was also made. The mediator model used linear regression with BMI as the outcome, while the primary outcome model used logistic regression for cardiometabolic disease and included both mobility-related disability and BMI. Both adjusted models included the prespecified covariates described above. A separate outcome model excluding BMI was used to estimate the association before adjustment for the mediator.

Ward-level cluster-robust standard errors were used for primary regression confidence intervals and p-values. Counterfactual mediation was implemented using the mediation package in R, specifying ward as the clustering variable with 5,000 quasi-Bayesian simulations [13]. With a logistic outcome model, the ACME, ADE, and total effect were interpreted on the response scale as average model-based differences in predicted outcome probability. Ward-level intraclass correlation coefficients were estimated using random-intercept models as sampling diagnostics. An exposure-by-BMI interaction was assessed, and diabetes and hypertension were analyzed separately. Leave-one-cluster-out analyses were performed across all 18 clusters.

To assess uncertainty with only 18 clusters, sensitivity analyses were conducted using CR2 cluster-robust covariance estimates with Satterthwaite degrees of freedom for the regression paths and 999 ward-level bootstrap replications for the mediation decomposition. The bootstrap resampled whole wards and generated percentile confidence intervals from standardized model predictions. There were no missing

values for the final model variables. Analyses were performed in R 4.5.1 (R Core Team, Vienna, Austria) with mediation 4.5.1 and clubSandwich 0.7.0; reporting was informed by the AGReMA statement [14].

Ethical approval

The ethical approval for the study was granted by the Institutional Ethics Committee of Jawaharlal Institute of Postgraduate Medical Education and Research (approval number: JIP/IEC-OS/199/2023, approval date: January 10, 2024). Written informed consent was obtained from all participants, and no identifying participant information is presented.

Results

Participant characteristics

Of the 1,436 eligible individuals approached across 943 households, 60 (4.2%) declined to participate, resulting in a final study sample of 1,376 participants (95.8%). Participants were enrolled from 18 wards/villages (mean cluster size, 76.4; range, 28-118), and all had complete data for the adjusted models. Mobility difficulty was reported by 144 participants (10.5%): 122 reported some difficulty, 18 reported a lot of difficulty, and four reported an inability to perform the assessed mobility activity. Compared with those without difficulty, participants reporting mobility difficulty were older, had higher mean BMI, and more frequently had hypertension and/or diabetes (Table *1*).

Characteristic	Overall (N = 1,376)	No difficulty (n = 1,232)	Any difficulty (n = 144)
Age, years	49.90 ± 15.84	48.25 ± 15.39	64.06 ± 12.15
Sex - male	476 (34.6%)	442 (35.9%)	34 (23.6%)
Sex - female	900 (65.4%)	790 (64.1%)	110 (76.4%)
BMI, kg/m²	26.17 ± 4.96	25.95 ± 4.67	28.04 ± 6.68
Hypertension	496 (36.0%)	426 (34.6%)	70 (48.6%)
Diabetes	190 (13.8%)	149 (12.1%)	41 (28.5%)
Hypertension and/or diabetes	586 (42.6%)	493 (40.0%)	93 (64.6%)
Family history of diabetes	329 (23.9%)	300 (24.4%)	29 (20.1%)
Family history of hypertension	329 (23.9%)	297 (24.1%)	32 (22.2%)
Socioeconomic status - Class I	181 (13.2%)	159 (12.9%)	22 (15.3%)
Socioeconomic status - Class II	485 (35.2%)	438 (35.6%)	47 (32.6%)
Socioeconomic status - Class III	278 (20.2%)	256 (20.8%)	22 (15.3%)
Socioeconomic status - Class IV	294 (21.4%)	262 (21.3%)	32 (22.2%)
Socioeconomic status - Class V	138 (10.0%)	117 (9.5%)	21 (14.6%)
Current tobacco use	45 (3.3%)	44 (3.6%)	1 (0.7%)
Current alcohol use	102 (7.4%)	100 (8.1%)	2 (1.4%)
Inadequate physical activity	1,180 (85.8%)	1,052 (85.4%)	128 (88.9%)
Inadequate fruit and vegetable intake	999 (72.6%)	880 (71.4%)	119 (82.6%)

TABLE 1: Participant characteristics by reported mobility difficulty (N = 1,376)

Categorical variables are presented as n (%) with denominators from the respective columns; continuous variables are presented as mean ± standard deviation. Socioeconomic status was classified using the modified B. G. Prasad scale for 2025. The primary exposure was any reported mobility difficulty. Comparisons are descriptive; no significance tests are presented.

BMI: body mass index

Cluster structure and path models

The ward-level intraclass correlation coefficient was 0.026 for BMI and 0.045 for cardiometabolic disease.

Based on the observed mean cluster size, the corresponding design effects were 2.92 and 4.41, supporting the use of statistical methods that account for clustering. In the primary cluster-robust regression analysis, adults with mobility-related disability had a 2.36 kg/m² higher mean BMI than those without mobility-related disability, after adjustment for covariates (95% CI: 1.04-3.68; p < 0.001). Each 1 kg/m² increase in BMI was associated with 1.08 times the odds of cardiometabolic disease after adjustment for mobility-related disability and other covariates (95% CI: 1.05-1.11; p < 0.001). Before adjustment for BMI, the association between mobility-related disability and cardiometabolic disease had an adjusted odds ratio (OR) of 1.58 (95% CI: 1.04-2.42; p = 0.033). After inclusion of BMI, the conditional OR was 1.34 (95% CI: 0.90-1.99; p = 0.155) (Table *2*).

Association	Crude estimate (95% CI)	Crude p-value	Adjusted estimate (95% CI)	Adjusted p-value
Mobility-related disability → BMI, β coefficient	2.10 (0.64-3.55)	0.005	2.36 (1.04-3.68)	<0.001
BMI → cardiometabolic disease, OR per 1 kg/m²	1.06 (1.03-1.08)	<0.001	1.08 (1.05-1.11)	<0.001
Mobility-related disability → cardiometabolic disease, total association OR	2.73 (1.91-3.90)	<0.001	1.58 (1.04-2.42)	0.033
Mobility-related disability → cardiometabolic disease after inclusion of BMI, OR	Not applicable	-	1.34 (0.90-1.99)	0.155

TABLE 2: Cluster-robust regression associations among mobility-related disability, BMI, and cardiometabolic disease (N = 1,376)

Adjusted models included age, sex, socioeconomic status, marital status, inadequate fruit and vegetable intake, tobacco use, alcohol use, family history of diabetes, and family history of hypertension. The BMI-to-cardiometabolic disease model additionally included mobility-related disability; the final conditional mobility-to-cardiometabolic disease model additionally included BMI. CIs and p-values use ward-level cluster-robust variance estimation.

BMI: body mass index, OR: odds ratio, CI: confidence interval

Primary mediation analysis

The cluster-adjusted mediation analysis identified a positive indirect association through BMI. The average ACME was 0.038 (95% CI: 0.015-0.067; p = 0.0004), corresponding to an approximately 3.8-percentage-point difference in the model-predicted probability of cardiometabolic disease attributable to the indirect component through BMI under the specified statistical model. The average ADE was 0.061 (95% CI: -0.025 to 0.143; p = 0.160), while the total effect was 0.099 (95% CI: 0.009-0.186; p = 0.032). The proportion-mediated point estimate was 0.374, with a wide 95% CI (0.117-1.743) (Table *3*).

Effect	Estimate	95% CI	p-value
ACME	0.038	0.015-0.067	0.0004
ADE	0.061	-0.025 to 0.143	0.1600
Total effect	0.099	0.009-0.186	0.0316
Proportion mediated	0.374	0.117-1.743	0.0312

TABLE 3: Cluster-adjusted mediation analysis of the association between mobility-related disability and cardiometabolic disease through BMI (N = 1,376)

Estimates are average model-based differences in predicted outcome probability on the response scale from 5,000 quasi-Bayesian simulations with clustering at the ward level. The proportion mediated is reported for completeness but interpreted cautiously because of its wide CI.

ACME: average causal mediation effect, ADE: average direct effect, CI: confidence interval, BMI: body mass index

Outcome-specific and robustness analyses

For diabetes, the ACME through BMI was 0.017 (95% CI: 0.006-0.031; p < 0.001), and the total effect was 0.085 (95% CI: 0.009-0.164; p = 0.023). The proportion-mediated point estimate was 0.193. For

hypertension, the indirect estimate was positive (ACME: 0.031; 95% CI: 0.010-0.058; p = 0.0004), whereas the estimated direct component was negative and imprecise, and the total effect was near zero. Therefore, the proportion mediated was not interpreted for hypertension (Table 4).

Outcome	ACME (95% CI)	p-value	ADE (95% CI)	p-value	Total effect (95% CI)	p-value	Proportion mediated (95% CI)	p-value
Diabetes	0.017 (0.006-0.031)	0.0004	0.068 (-0.004 to 0.144)	0.064	0.085 (0.009-0.164)	0.0228	0.193 (0.060-0.891)	0.0232
Hypertension	0.031 (0.010-0.058)	0.0004	-0.028 (-0.096 to 0.041)	0.430	0.004 (-0.077 to 0.087)	0.936	Not interpreted	-

TABLE 4: Outcome-specific cluster-adjusted mediation analyses (N = 1,376)

Effects are reported on the predicted-probability scale. The proportion mediated for hypertension was not interpreted because the total effect was approximately null.

ACME: average causal mediation effect, ADE: average direct effect, CI: confidence interval

There was no evidence of an exposure-by-BMI interaction in the cardiometabolic disease model (interaction coefficient: -0.023; p = 0.453). Across the 18 leave-one-cluster-out analyses, ACME estimates ranged from 0.031 to 0.044, with each confidence interval excluding zero. In additional analyses accounting for the small number of clusters, mobility-related disability remained positively associated with BMI (CR2-adjusted β: 2.36; 95% CI: 0.74-3.98; p = 0.009), while the total regression association with NCD was less precise (OR: 1.58; 95% CI: 0.96-2.60; p = 0.066). The ward-level bootstrap yielded an indirect estimate of 0.038 (95% percentile CI: 0.020-0.058), consistent in direction and magnitude with the primary estimate (Table 5).

Association or effect	Estimate	95% CI	p-value
CR2: mobility-related disability and BMI (adjusted mean difference, kg/m²)	2.36	0.74-3.98	0.009
CR2: mobility difficulty and NCD (adjusted OR, before BMI)	1.58	0.96-2.60	0.066
CR2: mobility difficulty and NCD (adjusted OR, after BMI)	1.34	0.84-2.13	0.194
CR2: BMI and NCD (adjusted OR per 1 kg/m²)	1.08	1.04-1.12	<0.001
Bootstrap: ACME	0.038	0.020-0.058	-
Bootstrap: ADE	0.061	−0.012 to 0.153	-
Bootstrap: total effect	0.100	0.017-0.196	-

TABLE 5: Sensitivity analyses using small-cluster-adjusted regression and ward-level bootstrap methods (N = 1,376)

For CR2 analyses, linear BMI and logistic NCD models were adjusted for age, sex, socioeconomic status, marital status, inadequate fruit and vegetable intake, current tobacco and alcohol use, and family history of diabetes and hypertension. The conditional cardiometabolic disease model included both mobility-related disability and BMI. CR2 intervals and Satterthwaite p-values account for 18 sampling clusters; these tests apply to regression coefficients, not to ACME. Ward-level bootstrap estimates used standardized g-computation with entire clusters resampled and 999 successful replications. Bootstrap confidence intervals are percentile intervals on the predicted-probability difference scale. These are sensitivity analyses; the original 5,000-simulation quasi-Bayesian estimates remain primary.

BMI: body mass index, NCD: noncommunicable disease, OR: odds ratio, CI: confidence interval, ACME: average causal mediation effect, ADE: average direct effect, CR2: bias-reduced cluster-robust variance estimator

Discussion

In this community-based study, mobility-related disability was associated with higher BMI, and BMI was positively associated with cardiometabolic disease. The mediation analysis identified a positive statistical indirect component through BMI that was stable across leave-one-cluster-out analyses and supported by a ward-level bootstrap. These findings suggest that adiposity warrants consideration when assessing cardiometabolic health in adults with mobility limitations. The pattern was more evident for diabetes than

for hypertension, underscoring the value of examining the two outcomes separately.

These findings align with previous evidence of a higher diabetes burden among adults with disabilities [4] and lower participation in recommended physical activity among people living with disabilities [5]. Disability-associated low energy expenditure and deconditioning may contribute to adverse metabolic profiles [6]. The mobility-adiposity relationship may also operate as a feedback loop: mobility limitations may reduce activity and alter body composition, whereas greater adiposity and cardiometabolic illness may subsequently worsen mobility [7]. A cross-sectional observation captures these potentially reciprocal processes at a single time point and cannot determine their temporal sequence. Consequently, imposing a one-direction exposure-BMI-outcome framework may introduce temporal bias into the estimated indirect component; the direction and magnitude of any such bias cannot be established from the present data [15,16]. Our cross-sectional findings should therefore be interpreted as associations within the specified conceptual model rather than as causal.

The South Asian setting is particularly relevant because cardiometabolic risk may occur at lower BMI levels in Asian populations [8], and Indian guidelines emphasize adiposity and fat distribution in metabolic risk assessment [9]. Recent ICMR-INDIAB findings also demonstrate that metabolic risk is not adequately captured by BMI-defined obesity alone [17]. BMI was a feasible, consistently measured population indicator in this household survey, but it does not distinguish fat from lean mass or characterize visceral adiposity or muscle function. Thus, sarcopenic obesity, which involves excess adiposity with reduced muscle mass and function, could not be identified [18]. The South Asian “thin-fat” phenotype further illustrates how excess body fat and metabolic vulnerability may occur despite a relatively modest BMI [19]. Using BMI as a proxy for adiposity may therefore misclassify these body-composition phenotypes and affect interpretation of the estimated indirect association.

For diabetes, the positive indirect component through BMI was accompanied by a positive total effect, supporting the hypothesis that adiposity may be an important intermediate pathway. For hypertension, the positive indirect component occurred alongside an imprecise direct component in the opposite direction and an essentially null total effect. Such opposing components are compatible with an inconsistent mediation or suppression pattern [20]. Because the total effect was near zero, a proportion-mediated estimate for hypertension would be unstable and was not interpreted.

The findings have practical implications for disability-inclusive NCD prevention. Adults with mobility limitations may face difficulties participating in standard lifestyle programs despite potentially elevated cardiometabolic risk. Community services could consider accessible weight management, individualized nutrition counseling, feasible physical activity, and hypertension/diabetes screening as components of inclusive risk assessment. Accessible, adapted activity approaches have been advocated for people with disabilities [21]. However, their effectiveness in reducing cardiometabolic events in this population requires prospective evaluation rather than inference from the present study.

The analysis has several strengths: a community-based urban-rural sample, a mobility-specific assessment rather than a heterogeneous composite disability indicator, measured BMI and cardiometabolic variables, a continuously modeled mediator, and explicit accommodation of within-ward clustering. The primary indirect estimate was consistent across all 18 leave-one-cluster-out analyses. CR2-adjusted regressions and a ward-level bootstrap additionally assessed uncertainty arising from the limited number of clusters.

The principal limitation is the cross-sectional study design, which prevents the determination of temporal ordering, reciprocal relationships, and reverse causation, thereby precluding causal inference. Although socioeconomic status was included in the adjusted models, residual confounding may persist within socioeconomic groups and from unmeasured chronic pain, depression, comorbidities, and treatment history. Survivor or selection bias is also possible if adults with more severe disabilities or cardiometabolic disease were less likely to survive or be available for household enrollment. Mobility limitations and behavioral exposures were self-reported; the translated rATA item was not formally psychometrically validated; and central adiposity was not measured. The unweighted sampling approach may limit generalizability, and with only 18 clusters, inferential precision remains a concern despite the sensitivity analyses.

Longitudinal cohorts with repeated assessments of mobility, cardiometabolic outcomes, and body composition are needed to distinguish reciprocal relationships and better evaluate mediation assumptions. Alongside BMI, future studies should assess waist circumference, fat and lean mass (using bioelectrical impedance or dual-energy X-ray absorptiometry where feasible), muscle strength, and time-varying factors such as physical activity, pain, depression, and treatment [16,18]. Pragmatic interventions should then evaluate the reach, feasibility, and clinical effects of adapted physical activity, individualized nutrition support, and integrated hypertension/diabetes screening within disability-inclusive community and primary-care services.

Conclusions

In this community-based cross-sectional study, mobility-related disability was associated with higher BMI,

and the mediation models identified a positive statistical indirect association through BMI with cardiometabolic disease, particularly diabetes. The finding was consistent across leave-one-cluster-out analyses and a ward-level bootstrap, supporting BMI as a relevant marker for further investigation in disability-inclusive cardiometabolic risk assessment. However, the observed associations do not establish the temporal or causal sequence between mobility limitation, adiposity, and disease.

These findings support accessible nutrition counseling, weight management, feasible physical activity, and routine hypertension and diabetes screening when planning community NCD services for adults with mobility limitations. Prospective evaluations should establish whether such disability-adapted approaches improve health outcomes.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Venkatachalam Jayaseelan, Vignesh Rajan S, Gayathri Mohan, Yuvaraj Krishnamoorthy, Kalaiselvy Arikrishnan, Ashoo Grover, Ravinder Singh

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Disclosures

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