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PHYSICAL FITNESS, BODY COMPOSITION, AND MOBILE HEALTH DESIGN NEEDS AMONG URBAN AND RURAL WOMEN IN PAKISTAN

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Abstract

Mobile health (mHealth) applications may expand access to physical-activity support, but their usefulness depends on the physical, social, and digital contexts of intended users. Evidence for women living in smaller urban and rural communities of Pakistan remains limited. This study compared anthropometric and field-based fitness profiles of urban and rural women in Bahawalnagar and interpreted the findings as design requirements for future mHealth physical-activity interventions. The study reported a quantitative cross-sectional comparison of 400 women (200 = urban and 200 = rural of 30-40 years of age. The source study used a structured health questionnaire, standardised anthropometry, and field fitness tests. Results showed that rural women were older by 1.88 years ($p = .023$), whereas urban women had a higher body mass index by 1.35 kg/m² ($p = .003$). Rural women had higher triceps, subscapular, iliac-crest, and front-thigh skinfold means (all adjusted $q < .01$). Results also showed that the rural women were superior in hand grip strength ($g = 0.76$), 30-second chair-stand repetition, and inferior in arm curls ($g = -0.43$) than the urban women. Future interventions therefore, focus on culturally appropriate designs and evaluate app engagement with objective physical-activity outcomes in prospective trials.

INTRODUCTION

Physical inactivity is a serious, growing and inequitable public-health challenge. According to global pooled surveillance, in 2022, 31.3% of adults were not getting recommended activity levels, and lack of activity was more common

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among women than men. Adults are advised to have 150-300 minutes of moderate activity and/or 75-150 minutes of vigorous activity each week, as well as muscle strengthening activities at least 2 days per week (World Health Organization, 2024). The clinical significance of these recommendations lies in the fact that regular movement is important for cardiovascular, metabolic, musculoskeletal and mental health, while inactivity is a risk factor for noncommunicable diseases and premature death (Bull et al., 2020; Strain et al., 2024). Fitness outcomes that are digitally supported also have varying degrees of support. (Rowland et al., 2024). Activity opportunities for women in low-resource contexts are influenced not only by their motivation, but also by their domestic workload, safety, mobility, time, climate, infrastructure, social norms, and others.

Mobile health is a form of healthcare service, information, monitoring or behavior change support provided via mobile and connected technologies. Typical physical-activity apps include self-monitoring, goal setting, reminders, feedback, instruction, social support and, in some cases, data from the wearable device's sensors. Such functions can decrease the need for a person to travel to a facility, and can make home-based activity possible. Public interest in health applications has long been demonstrated through national surveys, and awareness, perceived effort, social influence, and behavioral intention are key factors in continued use as suggested by adoption studies (Krebs & Duncan, 2015; Ndayizigamiye et al., 2020). Social support can also be reflected in women's participation (Sweeney et al., 2025). In theory these mechanisms apply to women who have limited opportunities to participate in organized exercise.

However, the effectiveness literature is not as sanguine as popular accounts of fitness apps. The results of a meta-analysis of randomized trials showed a small, though statistically questionable, improvement in objectively measured steps; longer interventions did show greater results (Romeo et al., 2019). A more recent pragmatic review highlighted the fact that many of these trials were conducted in contexts that do not fully reflect the delivery of ordinary services, with only modest advantages apparent, albeit these were only seen in shorter-term randomized trials (Stecher et al., 2023; Mönninghoff et al., 2021). Mobile interventions in the Middle East and North Africa (MENA) are still relatively limited and heterogeneous, with pooled results suggesting a potential for more active and less sedentary behaviors (Tong et al., 2024). A review of young women's experience of mobile apps in 2024 also showed positive trends but noted limited evidence due to inconsistent quality, self-reported results and the lack of an adequate application of behaviour change theory (Watson-Mackie et al, 2024).

Association of apps with body composition changes is also inconsistent. Cross-sectional studies sometimes claim the effects of the application, but this design cannot exclude the effects of other diet or co-interventions, or baseline motivation, or gym attendance (Albarrak et al., 2024). Much of the evidence in the 2024 Cochrane review of smartphone interventions for overweight or obesity was of uncertain quality and the interventions were not found to have lasting weight effects (Metzendorf et al., 2024). A newer study concluded that weight and waist outcomes, behaviors, and metabolic outcomes were positively affected by an app-based intervention with behavior change components, whereas the intervention content and engagement were also largely sources of heterogeneity (Li et al., 2025). Thus, an observational comparison of existing urban and rural groups cannot be said to constitute evidence of an application improving fitness unless exposure to the application, baseline fitness, adherence, and change over time were specified.

A handset is not a reliable tool for connectivity, private use, literacy, confidence, affordability or culturally relevant content. There is evidence that social position, residential area, language,

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disability, and material resources affect access, engagement, and distribution of benefits of digital diet and physical-activity interventions (König et al., 2025; Woolley et al., 2023). Similarly, implementation research in Pakistan shows that community-based technology can be acceptable when it is supported by trusted frontline workers, but training, workflow, connectivity, privacy, and contextual adaptation are critical (Akhtar et al., 2025). However, the issues are of major importance in a rural context like Punjab where the intermittent internet access, the use of phones (which are shared), the preference for local languages and the gendered decision-making power can affect the rate of initial adoption and how long people stay engaged.

The difference between technology acceptance and behavior change is a useful conceptual distinction. Acceptance models describe individual's expectations of usefulness, ease of use, social support, and feasibility of using an application. Behavior change frameworks have questions to ask about the application's ability to build capability, provide opportunity to engage in repeated behavior, and boost motivation to engage in repeated behavior. Awareness, effort expectancy, social influence, and intention had a significant portion of the mHealth use behavior, as feedback, credibility, personalization, and ease of use were discovered as factors influencing perceived value of mHealth in the qualitative research (Dennison et al., 2013; Ndayizigamiye et al., 2020). Poor step counts can lead to a decrease in trust, too many reminders can cause disengagement, competitive scoreboards can cause demoralization among novices, and the vague nature of exercise videos can make them dangerous for users who experience pain or have limited mobility. There is a large variation in both the content of digital interventions and their effectiveness in behaviour change, as revealed by reviews of behaviour change techniques (BCTs) (Direito et al., 2017; Eckerstorfer et al., 2018; Sweeney et al., 2025). Therefore, it is important that an evaluation document be prepared that not only shows that an application was installed but also documents which components were installed and utilized.

There are two ways the physical assessments can be used. Epidemiologically, they mean the variation in body composition and functional performance. There is no need to assert that residence is a biological exposure or that digital tools are beneficial in themselves. Rather, residence can be used to identify various environment-work-service-technology access combinations. This is consistent with an equity-minded mHealth strategy, which involves tailoring the content of the intervention to the user's context, and measuring success not just by the average amount of improvement, but by the ability to enroll, engage and derive benefit without undue burden for rural and less-educated populations.

The current study was conducted among the women of Daharanwala, a small urban is surrounded by a rural farming community, of District Bahawalnagar, Punjab, Pakistan. The study had three objectives: (1) to compare selected anthropometric characteristics of urban and rural women; (2) to compare field-based physical-fitness outcomes between the two residence groups; and (3) to translate the observed pattern, together with current evidence, into testable requirements for an equitable mHealth physical-activity intervention.

2. Methodology

2.1 Study Design and Reporting

The study was a quantitative, cross-sectional, two-group comparison, with one assessment period from Urban and Rural residence. The measurements were obtained as anthropometry, questionnaires and physical fitness with the following of STROBE guidance for observational studies by distinguishing design, participants, variables, measurement, bias, study size, and statistical methods (von Elm et al., 2007), and mERA principles (Agarwal et al., 2016).

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2.2 Setting, Population, and Sample

The reported target population comprised women aged 30-40 years living in urban and rural areas of Dahranwala, Tehsil Chishtian, District Bahawalnagar, Punjab, Pakistan. The analytic sample was 400 participants, divided equally between urban (n = 200) and rural (n = 200) residence. This study followed the convenient sample, along with other ethical parameters were followed as consent letter was obtained from all participants to ensure their volunteer participation in the study. The procedure of study was brief to the participant before the commence of data collection, along with inclusion and excluding criteria was adopted for data collection. Consequently, the method is best interpreted as a reported community sample with equal residence quotas; population representativeness cannot be confirmed. The study was informed and permission was obtained from the District Health Office, and ethical approval was obtained from the ethics-committee of the Islamia University of Bahawalpur, Pakistan.

2.3 Data-Collection Tools and Variables Description

Three tools were utilized in the source study. First a structured 25-item general-health and activity questionnaire measured perceived health, selected conditions, sleep, diet, social connection, screen use, leisure activity, farming work and perceived benefits of activity. The provided results did not list a separate validated scale for MHealth exposure, digital literacy, app engagement, and barriers, which means that the questionnaire cannot validate the impact of an app. Second, anthropometry comprised the standing height, body mass, body mass index (BMI), 7 reported skinfold sites, and selected circumferences. The height was measured using a stadiometer, the mass was measured using a digital scale, circumferences were measured using a nonelastic tape, and skinfold thickness was measured using a Harpenden-type caliper. BMI was defined as the weight (kg) by the height (m2). Third, a set of physical-fitness tests were planned and performed, comprising handgrip dynamometry, a 50-m walk timed, the 30-second chair stand, back-scratch flexibility, the 2-minute step test, one-leg stance, arm curl, and chair stand. Standardized field tests can be beneficial for community studies, as they are portable, inexpensive and can be interpreted, but need to be consistent at each site (Norton, 2018; Rikli & Jones, 2013).

2.4 Data collection was done by the following procedure:

The assessments were reportedly conducted during the morning hours in community or public settings, to minimize the impact of heat on performance variability. Height and weight were taken with shoes and heavy outer clothing removed. Participants in urban and rural group reportedly used the same equipment and assessors. Anthropometric landmarks were located prior to skinfold and circumference measurements and measurements were taken in the units measured by each instrument. The handgrip strength was measured using the best score the participant was able to obtain when standing and squeezing the dynamometer as hard as possible as per the thesis. The functional tests were conducted on a stable surface using verbal instructions that were standardized in terms of the content and timing (Norton, 2018; Rikli & Jones, 2013).

2.5 Reliability and Measurement Quality

They reported ICC/r values of .93 to .99 for anthropometric variables and .90 to .96 for fitness tests for their thesis. These values are indicative of high repeatability, but the number of participants for the reliability subsample, retest interval, ICC model, confidence intervals, and the type of correlation (Pearson or intraclass) were not reported. They are therefore reported, not as independent reliability assessments, but as 'coefficients'. The item-total correlations for the 25 items on the questionnaire ranged from .214 to .812. An item-total correlation is used to replace scale level internal consistency and the items are

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heterogeneous health behaviors and conditions and are not necessarily to be combined into one score.

2.6 Normality

Normality and statistical assumptions. There were no participant-level distributions, histograms, Q-Q plots, Shapiro-Wilk statistics, outliers and/or Levene tests available or could not be reconstructed from summary statistics. To make up a table of normalities is not scientifically correct. The sampling distribution of the mean is quite reliable in the face of moderate nonnormality, but not robust against severe outliers, coding errors or clustered sampling. Due to the lack of equal variance in the population and the general preference of Welch's t-test when variances of the groups might not be equal, this approach was selected (Delacre et al., 2017). Ordinal level of measurement for qualification codes for each disease and questionnaire items were not reanalyzed as continuous outcomes due to lack of information about the definitions of each level and the distributions of each item at the level of the participants. (Lakens, 2013).

2.7 Statistical Analysis

Data are presented as mean ± SEM. The rural minus urban difference was examined for each recoverable continuous outcome using a two-sided independent-samples t test (Welch approximation). 95% confidence intervals are used to convey uncertainty. The standardized differences are Hedges g values that represent the difference between the rural and urban mean values and make use of the pooled standard deviation, corrected for small sample size; positive g values indicate higher rural mean values and negative g values indicate higher urban mean values. The false discovery rate was controlled for using Benjamini-Hochberg adjustment in each family of outcomes, and $p < .05$ was considered statistically significant. The p-values are reported where appropriate, otherwise < .001 is reported. The recalculations were done from published summaries and are appropriate for internal consistency checking, but will not recreate missingness decisions, distributional checks, covariate adjustment, or sensitivity analyses that are robust (Delacre et al., 2017; Lakens, 2013).

Results

Analytic verification and assumptions. All four core participant-characteristic outcomes and all seven skinfold outcomes had complete group means and standard deviations. There were also eight measures of plausibly aligned circumference outcomes and eight fitness outcomes that were also recoverable. Four rows were not included in the breadth/length rows because the source table contained apparent displacement of rows or an implausible standard deviation. The normality and homogeneity test statistic mentioned in the thesis were not followed by the output of the test scores, therefore they are not reported as observed findings. In the following article, t-test columns have been replaced by Welch tests.

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Figure 1. Participant characteristics by residence

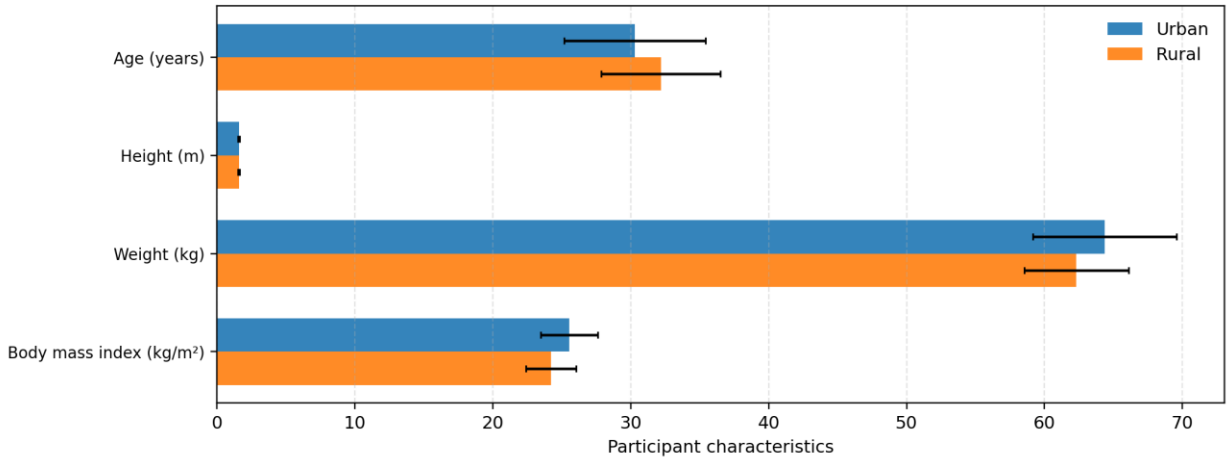


Figure 1. Participant characteristics by residence

Note. The group mean shown by a bar; error bars are ± 1 standard deviation (SD). These are descriptive comparisons.

Participant characteristics. The average age of the rural participants was 1.88 years older than the urban participants (95% CI [0.25, 3.51]; p = .023); however, the standardized difference was small (g = 0.23). There was no difference in mean height. The mean weight difference was 2.05 kg for the urban participants with a confidence interval that included zero, p = .055. Mean BMI was 1.35 kg/m² higher in urban women, 95% CI [0.47, 2.23], p = .003, g = -0.30. Only BMI was below q = .05 after the correction of this four-outcome family. The group mean BMI for both groups was in the normal overweight range but the classification of each individual cannot be inferred from a mean.

Figure 2. Skinfold thickness by residence

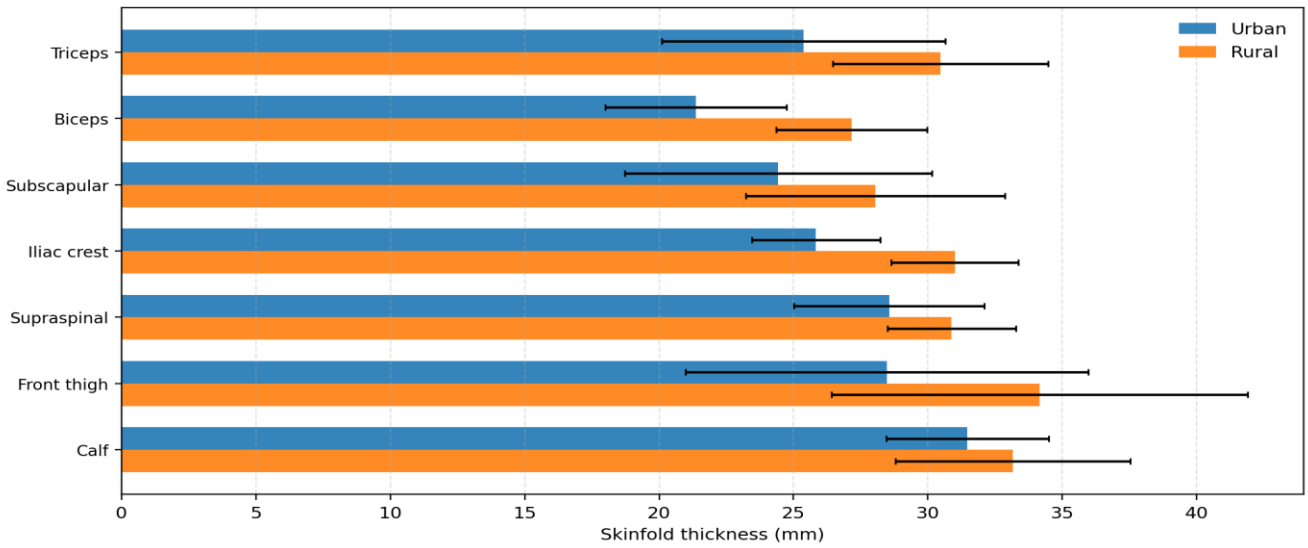


Figure 2. Skinfold thickness (by residence)

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Note. These are descriptive comparisons and not confidence intervals.

Skinfold profile. At all reported sites, rural was greater than urban. Differences were most pronounced for the triceps (5.08 mm), subscapular (3.62 mm), iliac crest (5.17 mm) and front thigh (5.68 mm), all of which remained $q < .01$. The large standard deviation (21.37 mm) of the urban population compared with the mean and other sites, made the biceps estimate less precise. The differences between supraspinal and calf were small and were not significant even after adjusting for the FDR. The pattern suggests regional variations in SFA distribution, but it is not a body-fat equation or an app effect; it should not be used without validated body-fat equations.

Figure 3. Circumference outcomes by residence

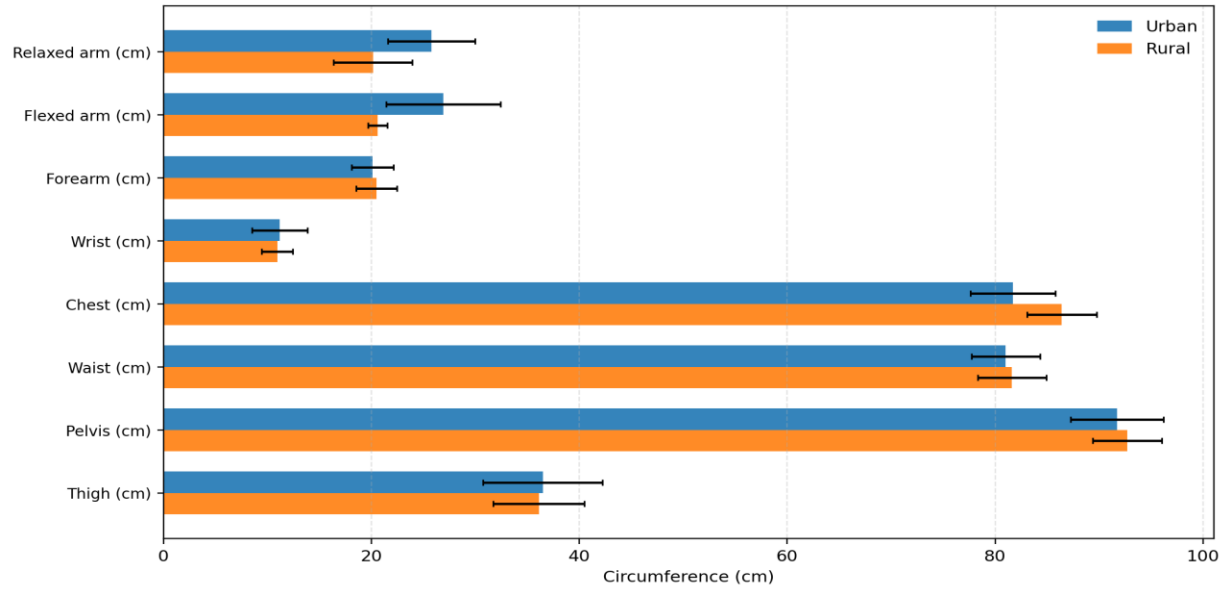


Figure 3. The results of the circumference are displayed by residence.

Note. Group means are represented by bars, and error bars with ±1 standard deviation (SD). These are not confidence intervals but are descriptive comparisons.

Circumference profile. Large urban advantages were observed for circumference of relaxed and flexed arms, whereas rural women had a moderately larger mean chest circumference, as revealed by recoverable circumference summaries. Differences in the forearms, wrists, waist, pelvis and thighs were small. The results are suggestive, but need to be verified with the participant-level records in the original table due to the narrow standard deviations of the arms values among the rural participants and the displacement of several arms value rows. They are kept in a clearly qualified table for transparency, not as a definitive evidence.

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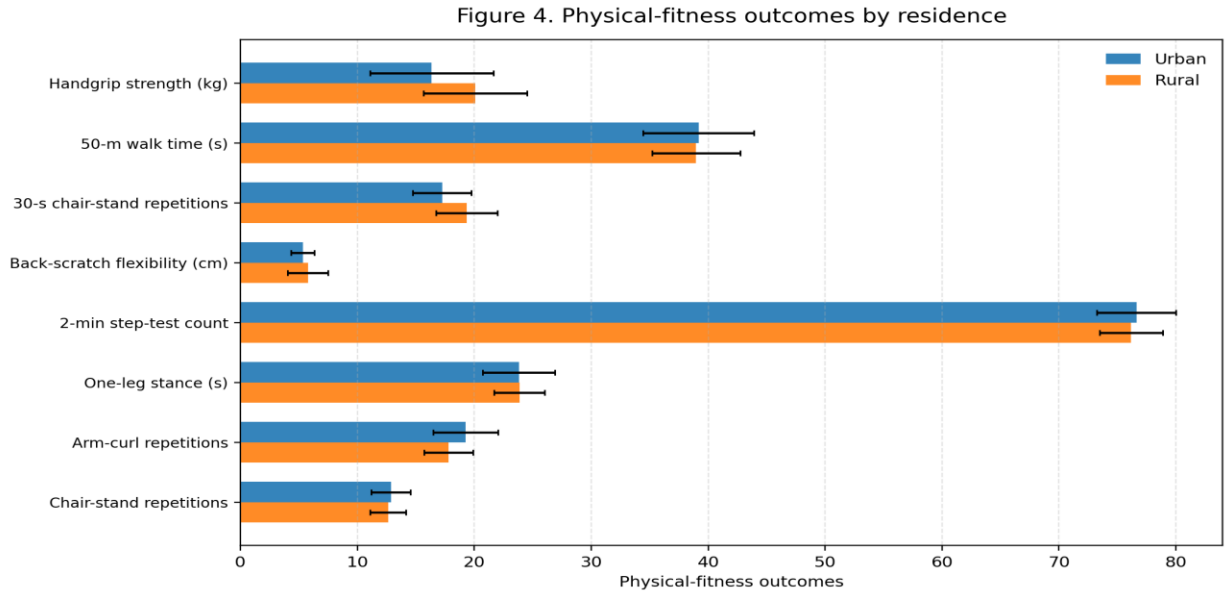


Figure 4. Physical-fitness results for living place

Note. All bars indicate group means and error bars indicate ±1 standard deviation (SD). These are descriptive comparisons and NOT confidence intervals.

Rural women had higher handgrip strength by 3.71 kg, 95% CI [2.75, 4.67], $p < .001$, $g = 0.76$, and completed 2.13 more repetitions on the 30-second chair-stand measure, 95% CI [1.33, 2.93], $p < .001$, $g = 0.52$. The contrast rural minus urban was found to be $g = -0.43$, corresponding to a difference of 1.48 more arm-curl repetitions for urban women (95% CI [0.80, 2.16], $p < .001$). There was no significant difference between the groups in 50-m walk time, back-scratch flexibility, two-minute step count, one-leg stance, or extra chair-stand count. These mixed findings suggest that neither a simple urban-better nor a rural-better treatment is warranted.

Effect-size synthesis. Figure 1 standardises the anthropometric and fitness data on a common scale. Positive means indicate an increase in the rural mean. The strongest rural and urban differences among the retained measurements of fitness were for handgrip strength and selected skinfolds.The largest rural-urban difference among the retained fitness measures was arm-curl performance. Four selected fitness outcomes are presented in terms of group means and 95% CI in Figure 2. These plots highlight magnitude and uncertainty, not just statistical significance, particularly when n = 200 per group. Points are Hedges g and approximate 95% confidence intervals (bars). High rural means are represented by positive values.

4. Discussion

The updated analysis revealed three key findings. First, women in urban and rural areas were not all different in the fitness categories. Rural participants performed more arm curls, had more 30-second chair-stand performance, and greater handgrip strength than the urban participants, who had a higher average BMI. Second, although rural women performed better on some of the strength tasks, they also had higher means at several skinfold sites, demonstrating that adiposity and functional capacity are separate constructs. Third, there was no testing of the source data to determine if an mHealth application contributed to any of these differences? Their greatest addition is to describe two user groups for whom the future of digital physical-activity support should be

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created and tested in a prospective study (Rowland et al., 2024; Tong et al., 2024).

The higher handgrip and chair-stand may relate to the lifestyle of the person, such as lifting, carrying, walking, squatting, and farming. Any exercise that helps to build task-specific strength may be beneficial but does not always satisfy structured aerobic and muscle-strengthening guidelines (Bull et al., 2020; World Health Organization, 2020). On the other hand, people living in urban areas might have more information, access to structured exercise opportunities and mobile connectivity, along with more sedentary time and access to energy-dense foods. This is consistent with the higher BMI for the cities but cannot be ruled out by the cross-sectional design due to behavioral pathways, age, education, income, parity, diet, or selection. The rural group was a little older and even a small age difference can have an impact on body composition or test performance. To draw conclusions on the differences in residence, lifestyle needs to be considered, and participant level adjusted analyses must be carried out (Strain et al., 2024; von Elm et al., 2007).

The findings from the skinfold calls for a similar interpretation. The increased thickness at several sites in the rural regions could reflect increased subcutaneous adiposity but the mean BMI was not increased. BMI doesn't differentiate fat from lean mass and doesn't describe fat distribution and skinfold measurements are affected by a variety of factors such as landmarking, caliper pressure, assessor technique and prediction equations (Norton, 2018). The Supraspinal and Biceps standard deviations are unusually large in the urban group, suggesting the presence of data entry errors, non-uniform distribution or outliers. A future study should repeat or replicate measurements and report the technical error of measurement; set an a priori tolerance level; and report the equation used to estimate body density or body-fat percentage. Other parameters of the device and device calibration should also be documented (Albarrak et al., 2024; Li et al., 2025; Metzendorf et al., 2024).

The fitness pattern emphasizes the need for a multidimensional approach to assessment. Although handgrip strength is a general index of upper-limb strength, arm-curl repetitions require repeated movement, correct form, swing speed and local muscular endurance. Chair stand tests are also dependent on precise timing and directions (Rikli & Jones, 2013). The source document is ambiguous with respect to the two protocols: 20 seconds and 30 seconds. The only result with a clear label that was interpreted as such was the 30 second result; the other lower body result was left as is, with its reported label. Standardisation of test duration, practice trials, control on rest and specifications of terminating criteria would enhance comparability. The high similarity in the 50-m walk, step, balance and flexibility outcomes suggests that the outcomes would not vary much based on residence alone (Rowland et al., 2024; Tong et al., 2024).

In the case of mHealth design, mixed baseline profiles are better suited for personalization, rather than one generic program. Elementary strength content may be sufficient for rural users whose task-specific performance is relatively strong, but who might benefit from mobility, recovery, safe lifting, joint protection and progressive aerobic modules instead. Slow progressive resistance training, walking goals, and nutrition-support features can be helpful to urban users with higher BMI and/or lower handgrip or chair-stand performance. These are design hypotheses not clinical prescriptions! An application should include a short screening and baseline assessment followed by setting goals based on functional capacity, health status, pregnancy status, user preference. Automated progression should be reserved for minimal and be accompanied by explicit warnings to halt and seek treatment when warning warnings are present. Personalization and social support should be explored (Sweeney et al., 2025; Watson-Mackie et al., 2024).

Features that promote behavior change should be evidence- and cost-effective. The more frequently

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occurring features in effective digital interventions include goal setting, self-monitoring, feedback, prompts, graded tasks, and social support, but not all additional features are necessarily more effective at increasing engagement. However, a recent meta-analysis of app-based weight interventions conducted in 2025 revealed positive effects on selected outcomes and a significant effect of the intervention resources and context (Li et al., 2025). Previous reviews also indicate that effects tend to be small and can weaken over time (Mönninghoff et al., 2021; Romeo et al., 2019) (Sweeney et al., 2025).

Designs need to be equitable. Exercise videos and audio instructions, log and reminders should be able to operate without continuous data, so that they are available offline. Use of audio (in Urdu and Punjabi) can minimize the burden of reading and simple icons and demonstration videos can assist users who have different levels of literacy. Low-end support, limited download, low battery consumption and inclusion of SMS or interactive-voice feature would expand the audience. Be careful that the lock screen of the shared-phone doesn't show sensitive health data. The timing of notifications should be at user's control, and only necessary data should be collected. CHWs/ trained female facilitators may assist in induction and proper exercise form. The blended approach is supported by evidence from Pakistan and the results of inequality reviews (Akhtar et al., 2025; König et al., 2025; Woolley et al., 2023).

The results need to be placed in context of the evidence. Physical-activity interventions in mHealth have been seen as potential and not only in consistent terms but also with limitations in follow-up duration and representativeness in real life (Rowland et al., 2024; Stecher et al., 2023; Tong et al., 2024). There is also a specific lack of evidence towards young women, as well as a high proportion of evidence that is self-reported (Watson-Mackie et al., 2024). Digital-health inequities may manifest at the access, adoption, engagement, and outcome levels (König et al., 2025; Woolley et al., 2023). A future intervention in Bahawalnagar should then report on reach just as carefully as efficacy – how many women were eligible, contacted, reached a phone, enrolled, active at each time point, and retained.

On a methodological level, the figures have been adjusted and this also affects interpretation of the original figures. The presented means and standard deviations for several reported t values could not have been what they are if the number of subjects were the same in each group. For example, there was no significant difference between the balances means, as determined by recalculation, and the large handgrip difference was highly significant. This is why it is advisable to report means and dispersion together with sample sizes, effect estimates and confidence intervals (Lakens, 2013).

Also, by applying false-discovery-rate adjustment, the likelihood of false positive findings in a large battery of tests is diminished. The corrected tables should only supersede the original inferential columns after the tables have been compared to the raw SPSS file (Agarwal et al., 2016; von Elm et al., 2007).

However, Study provides a valuable starting point. It includes equal number of urban and rural respondents, incorporates body dimensions and multiple functional assessments, and emphasizes women outside of larger metropolitan areas. The results, when corrected and clearly set against a context, pinpoint differences as starting points for intervention content and stratification. The next step should not be a general sweeping statement on the effectiveness of apps. It should be a feasibility study that is co-designed and a controlled trial with appropriate sample size and with prespecified outcomes, and equity-stratified report (Agarwal et al., 2016; König et al., 2025; Sweeney et al., 2025).

5. Conclusion

The anthropometric and fitness profiles of urban and rural women were different but similar for women from the reported sample of Bahawalnagar. The handgrip strength and 30-

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second chair-stand performance were greater in rural women and mean skinfold thickness was greater at several sites, while mean BMI and arm-curl performance were greater in urban women. There were many other differences that were minor. The findings found in these residences are not evidence of mHealth effects, when prospective exposure and outcome is not measured (Rowland et al., 2024; Tong et al., 2024). App exposure, engagement and changes over time were not well measured in the source study. Future programs should then be helped to be personalized, adapted to culture and language, accessible in case of intermittent connectivity and transparently evaluated. Evaluation should be conducted across social groups, record intervention dose and trialled mechanisms for engaging women (Agarwal et al., 2016; König et al., 2025; Sweeney et al., 2025; Woolley et al., 2023).

6. Recommendations

Build a low data application to be used offline as well as to support inexpensive Android phones with Urdu and Punjabi audio, illustrated exercise instructions, adjustable reminders. Research and pilot private, household acceptable, communally-used phones and develop content with urban and rural women, PE specialists, clinicians, and female community health workers; test before deployment. Design a design that is prospective. Before recruitment, a pilot randomized or stepped-wedge trial should identify the app, comparator, intervention dose, follow-up period and one primary outcome.

Weeks active, completed sessions, eligibility, phone access, enrollment, reasons for nonuse, and attrition. Consider urban-rural differences at each stage. Where possible, objective activity measures (for example, validated step count or accelerometry) are used, alongside standardised fitness tests and well documented anthropometry. Before replacing with corrected summary results – recheck all values, units, outliers, missingness, normality plots, table alignment before replacing.

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