

Evaluation of Longitudinal Impact of Structured Physical Activity on Dermatological Health Outcomes and Its Associated Economic, Productivity, and Healthcare Utilization Implications

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Abstract

Background: The skin is the largest organ of the body and its barrier systems are complex and may be altered by exercise due to the increase in the vascular blood flow, endocrine functions, and metabolism. Moreover, dermatological diseases are associated with a significant financial cost in terms of direct health care expenditure, loss of productivity and reduced health related quality of life, which can be mitigated by routine physical exercise. Hence the purpose of the study was to assess the longitudinal association between structured physical activity and dermatological health outcomes and the economic and healthcare utilization consequences.

Methodology: Our study was a prospective cohort study that followed 385 healthy persons aged 25-55 years over 12 months. The participants of the study were divided into four separate groups including inactive controls (n=96), moderate cardiovascular exercisers (n=97), high-intensity interval participants (n=96), and multimodal training practitioners (n=96). Primary outcomes included transepidermal water loss, cutaneous hydration and dermal elasticity measures using standardized equipment at baseline, six months, and 12 months. Secondary outcomes were related to healthcare use in dermatology, out-of-pocket spending, work productivity impairment measured with the Work Productivity and Activity Impairment (WPAI) questionnaire, and dermatology-specific quality of life measured with the Dermatology Life Quality Index (DLQI).

Results: After twelve months, cutaneous hydration increased by 17.2, 15.8, and 20.4% among moderate cardiovascular exercisers, high intensity interval exercisers, and multimodal training exercisers respectively (p<0.001). Dermal elasticity enhanced by 19.1%, 16.7%, and 22.3% respectively (p<0.001). The trans epidermal water loss reduced substantially in all exercise groups (p<0.01). Active participants were found to have 44-56% fewer visits to dermatology clinics, 37-73% reduced use of prescription medications, and PKR 17,500-23,900 in annual per-patient cost reductions compared to sedentary controls. The impairment of work productivity was reduced by 40-58% within exercise groups and the DLQI scores were significantly increased. Cutaneous complications related to exercise occurred in 13.2% of active participants and were mostly mild and short-term.

Conclusion: Multimodal cardiovascular-resistance training proved to be the best in all areas. These findings justify exercise as a cost-effective and primary intervention to improve dermatological health with a high benefit to the individual and healthcare system.

Keywords: Barrier Function, Dermatology, Dermatology Life Quality Index, Exercise, Economic Burden, Healthcare Utilization, Skin Health, Transepidermal Water Loss, Work Productivity

1. INTRODUCTION

The human skin is the largest organ system of the body that provides important protection against the environment as well as maintains physiological balance that protects against environmental threats (Huston 1). The stratum corneum is the surface of the epidermis that is directly involved in the minimization of transepidermal water loss and maintenance of cutaneous moisture due to its complex structure of corneocytes and intercellular lipid matrices.

Physical activity is one of the main elements of preventive healthcare, providing proven benefits in cardiovascular health, metabolic, immune system, and psychological health. Physiological effects of exercise include better circulation, endocrine, anti-inflammatory, and enhanced cell metabolism that may affect the health of the skin through various mechanisms.

Outside the biological sphere, dermatological disorders have a significant and largely underestimated economic cost both at the personal and societal levels. Patients with chronic or recurring skin conditions are often facing huge out-of-pocket costs on prescription drugs, specialist visits, and non-prescription skin care items. In addition, skin illnesses have a significant role as contributors to absenteeism, presenteeism, and the overall loss of work productivity, and studies based on population results have estimated that dermatological illnesses cause millions of lost workdays every year. In spite of these implications, the degree to which organized physical activity can alleviate the economic and productivity cost of dermatological ill-health is virtually uninvestigated in prospective longitudinal studies.

The exercise skin health relationship exists through linked processes of improved microvascular perfusion, optimal nutrient delivery, improved lymphatic drainage, and regulation of stress hormones that regulate collagen synthesis and cellular repair processes. Also, exercise impacts the secretion of growth hormone, the expression of insulin-like growth factor, and activity of antioxidant enzymes, which all contribute to maintain the youthful aspects of the skin and counter oxidation-induced damage

While theoretical foundations inform on the effects of exercise on skin health, the amount of empirical evidence, particularly by methodologically robust prospective studies with sufficiently long follow-up, to guide the sustained associations between exercise patterns and skin health is limited. The association between exercise intensity and the ability to hydrate skin has only been made with cross-sectional studies, and there is little information on the effects of moderate and long-term exercise patterns on the skin health, health care use and economic impact in the population in general. This research was meant to fill these knowledge gaps by investigating connections between predetermined exercise habits and objective cutaneous health variables, the amount of healthcare resource use, productivity, and economic load over a twelve-month follow-up.

2. METHODOLOGY

2.1. Study Design and Setting

The study was a prospective observational cohort study that was done in the Benazir Skin and Laser Clinic in Hyderabad, Sindh between July 2024 and July 2025. The study design was based on the STROBE guidelines of observational studies and it was ethically approved by the Institutional Review Board of Benazir Skin and Laser clinic (IRB Protocol Number: BSLC-IRB/2024/011), Hyderabad, Sindh. All the study procedures were conducted according to the principles of the Declaration of Helsinki and Good Clinical Practice guidelines.

2.2. Sample Size Calculation

G*Power statistical software version 3.1.9.7 was used to analyse power. A sample size was calculated to detect a difference of 12% between groups on skin hydration and elasticity parameters based on pilot data (standard deviation of 12% and 18%, respectively) and assumptions of detection of a difference of 12% between groups at 80 percent power, $\alpha=0.05$ (two-tailed) and effect size of 0.65. The necessary sample size, adjusted to account for 15 percent attrition rate, was 85 participants per group ($n=340$), which was raised to 96 ($n=384$) to increase the power of the study and allow the opportunity to address possible clustering effects.

2.3. Participant Recruitment and Selection

The participants were recruited using a multi-channel strategy that comprised of advertisements in local newspapers, social media campaigns targeting adults in the age range of 25-55 years, partnership with fitness facilities, collaboration with primary care practices, and distribution of information material during community health events. The application date was between May 1, 2024 and June 30, 2024.

Purposive allocation of stratified convenience sampling was used such that the representation was balanced across the groups of exercises. The population of interest included adults from the metropolitan area, the sample was stratified by age (25 to 34, 35 to 44, 45 to 55 years), sex and exercise frequency at baseline.

2.4. Inclusion Criteria

- Age 25–55 years at enrollment
- Residence within 50 km of the research center.
- Exercised regularly for ≥ 6 months before enrollment.
- Body mass index 18.5–35 kg/m^2
- No acute illness in previous 4 weeks
- Medically stable on medications for ≥ 3 months.
- Signed informed consent form and willingness to attend all visits.

2.5. Exclusion Criteria

- Current dermatological diseases being treated with prescription medication.
- Systemic conditions affecting skin physiology (diabetes, autoimmune conditions).
- Use of medications affecting skin barrier (topical steroids, retinoids).
- Pregnancy or nursing status
- Cosmetic/dermatological surgery within the past 6 months.
- Anticipated major life changes during study.
- Limited ability to exercise due to musculoskeletal or cardiovascular factors.

2.6. Exercise Group Classification

Prospective group classification was made according to exercise patterns in the prior six months:

Sedentary Control Group (n=96):

<75 minutes of planned physical activity per week; sedentary time >8 hours per day (validated by accelerometry); VO_2 max <25 ml/kg/min (males) or <20 ml/kg/min (females); self-reported physical activity questionnaire score <600 MET-minutes/week.

Moderate Cardiovascular Exercise Group (n=97):

150-300 minutes of moderate cardiovascular activities per week; exercise heart rate at 40-60% of heart rate reserve; activities such as brisk walking (≥ 4.8 km/h), leisurely cycling, swimming; VO_2 max 25-35 ml/kg/min; no regular resistance training (≤ 1 session monthly).

High-Intensity Interval Training Group (n=96):

≥ 75 minutes per week of vigorous exercise at >85% heart rate reserve; interval exercise protocols (1:1 to 4:1 work:rest ratio); activities such as sprint intervals, circuit training, competitive sports; peak power output >250 watts (males) or >150 watts (females); recovery heart rate < 120 bpm within 3 minutes after exercise.

Multimodal Training Group (n=96):

At least 150 minutes of cardiovascular exercise weekly (40-70% heart rate reserve); at least 2 days weekly of resistance exercise targeting major muscle groups; resistance exercise: 8-12 repetitions with 60-80% one-repetition maximum; proficiency in both exercise modes for at least 6 months.

2.7. Outcome Measurements

Key outcome measures were objective measures of barrier function and physiology using validated non-invasive methods.

Transepidermal water loss (TEWL) was measured using the Tewameter[®] TM 300 (Courage + Khazaka Electronic GmbH, Cologne, Germany), which quantifies water diffusion across the stratum corneum per unit area and time.⁷ Measurements were obtained at standardized anatomical sites including the cheek, forehead, and volar forearm following a 20-minute acclimatization period, with values expressed in g/m²/h.⁸

Skin hydration was assessed using the Corneometer[®] CM 825 (Courage + Khazaka Electronic GmbH), which measures stratum corneum water content through electrical capacitance and provides reliable, reproducible measurements expressed in arbitrary units (AU) that correlate with skin moisture content.⁹

Skin elasticity was evaluated using the Cutometer[®] dual MPA 580 (Courage + Khazaka Electronic GmbH), which applies controlled suction to skin surfaces and measures deformation and recovery patterns, with parameters including R2 (gross elasticity), R5 (net elasticity), and R7 (biological elasticity).⁹

Secondary outcome measures included standardized clinical skin examinations conducted by board-certified dermatologists, high-resolution photographic documentation using the VISIA[®] Complexion Analysis system, and systematic monitoring of exercise-related adverse events through monthly questionnaires and clinical examinations.¹⁰⁻¹¹

2.8. Economic and Healthcare Utilization Outcomes (Secondary Endpoints)

Alongside the biophysical skin measurements, a range of secondary outcomes were prospectively assessed to assess the financial and productivity effects of exercise related changes in dermatological health. These include:

- *Dermatology-related healthcare utilization:* Frequency of outpatient dermatology appointments per year, ascertained through medical record review and participant self-report based on appointment cards.
- *Prescription medication use:* Percentage of participants needing prescription dermatological medications at any time of the 12-month study period, through pharmacy databases and participant recall.
- *Out-of-pocket expenditure:* Monthly self-reported out-of-pocket costs for over-the-counter (OTC) skincare and dermatological products, in Pakistani Rupees (PKR) reported through validated expenditure diaries.
- *Work productivity and activity impairment:* Measured using the Dermatology-specific Work Productivity and Activity Impairment (WPAI:Derm) questionnaire at baseline, 6 months and 12 months, including absenteeism (time off work) and presenteeism (impairment while at work) due to skin diseases.
- *Health-related quality of life:* Assessed with the Dermatology Life Quality Index (DLQI), a 10-item questionnaire scored 0-30 (higher scores reflect lower quality of life), at all three time points.
- *Total annual dermatology-related cost per patient:* Estimated as direct (clinic visits, prescription medications, OTC medications, and products) and indirect (productivity loss valued using average daily wage estimates) costs in PKR.

2.9. Confounding Variables Assessment

This assessment was thorough to allow for proper adjustment in statistical analysis and to improve the study's validity by including demographic data, health and lifestyle parameters such as smoking status, sleep quality, environmental and occupational exposures, as well as body composition using dual-energy X-ray absorptiometry (DEXA).

2.10. Statistical Analysis Plan

Continuous variables were tested for normality using Shapiro-Wilk tests (for sample sizes <50) and Kolmogorov-Smirnov tests (for larger sample sizes), Q-Q plots, and visual inspection of histograms. Continuous variables found not to be normally distributed were log-transformed or non-parametric analyses were used.

Primary Analysis:

Multiple linear regression was used to assess change in continuous skin parameters from baseline to 12 months, key variable being exercise group. Models were adjusted for baseline values, demographics, BMI, smoking and other variables of interest.

Secondary Analysis:

Analysis of variance (ANOVA) was used to compare means and Tukey's honestly significant difference (HSD) to determine post-hoc differences. Cohen's d was used to calculate effect sizes. For economic and utilisation outcomes, Poisson regression models were applied to count data (number of clinic visits); logistic regression models to binary data (medication use); and generalised linear models to continuous economic data. Multiple imputation by chained equations (MICE) (20 imputations) was used to handle

missing data. Analyses adhered to intention-to-treat. A two-tailed p-value < 0.05 was considered statistically significant. All analyses were performed using R software version 4.3.0.

3. RESULTS

3.1. Participant Characteristics and Flow

The recruitment process concluded on June 30, 2024, during which 847 individuals expressed interest in study participation. Of these, 523 individuals completed preliminary telephone screening, with 467 meeting basic eligibility criteria. Following detailed screening procedures, 82 individuals were excluded due to medical conditions, medication use, or inability to commit to follow-up requirements, resulting in 385 participants enrolled in the final cohort. At 12 months, retention was excellent with 344 participants (89.4%) completing final assessments. Loss to follow-up was similar across groups: sedentary controls 11 participants (11.5%), moderate cardiovascular 9 participants (9.3%), high-intensity interval training 10 participants (10.4%), and multimodal training 11 participants (11.5%). Baseline characteristics were well-balanced across groups, with sedentary participants showing higher BMI ($27.2 \pm 4.8 \text{ kg/m}^2$) compared to active groups ($24.8\text{--}25.1 \text{ kg/m}^2$, $p=0.003$) and poorer sleep quality (Table 1).

Characteristic	Sedentary Controls (n=96)	Moderate Cardiovascular (n=97)	HIIT (n=96)	Multimodal Training (n=96)	p-value
Demographics					
Age, years	42.3 ± 9.1	41.8 ± 8.7	42.2 ± 8.9	42.1 ± 8.6	0.94
Female sex	61 (63.5)	59 (60.8)	60 (62.5)	58 (60.4)	0.93
Anthropometric Measures					
BMI, kg/m ²	27.2 ± 4.8	25.1 ± 3.9	24.8 ± 3.7	24.9 ± 3.8	0.003
Lifestyle Factors					
Current smokers	9 (9.4)	6 (6.2)	5 (5.2)	7 (7.3)	0.67
Sleep quality score	6.8 ± 2.1	5.9 ± 1.8	6.1 ± 1.9	5.8 ± 1.7	0.002
Baseline Skin Parameters					
TEWL, g/m ² /h	15.1 ± 3.4	14.6 ± 3.2	14.8 ± 3.1	14.7 ± 3.3	0.73
Skin hydration, AU	41.8 ± 9.2	42.4 ± 8.9	42.1 ± 9.1	42.6 ± 8.7	0.84
Skin elasticity R2, %	67.9 ± 12.8	68.7 ± 11.9	68.4 ± 12.3	68.9 ± 12.1	0.89
<i>BMI = body mass index; HIIT = high-intensity interval training; TEWL = transepidermal water loss; AU = arbitrary units;</i>					

Table 1: Baseline Demographic and Clinical Characteristics

3.2. Exercise Pattern Adherence and Monitoring

Exercise pattern consistency throughout the 12-month observation period was outstanding, with 91% of participants maintaining their baseline exercise classification throughout follow-up. Monthly monitoring contacts revealed high adherence to established exercise routines, with activity tracker data confirming self-reported exercise patterns in 94% of participants. Moderate cardiovascular exercisers maintained an average of 187±42 minutes of weekly exercise, high-intensity interval training participants averaged 98±23 minutes of vigorous exercise weekly, and multimodal training participants averaged 201±38 minutes of cardiovascular exercise plus 2.4±0.6 resistance training sessions weekly.

3.3. Primary Skin Health Outcomes

Significant results in skin health parameters were seen across all exercise groups in comparison to the sedentary controls. Exercise participants showed the most significant improvements in skin hydration with moderate cardiovascular exercise participants registering a 17.2% increase, the high-intensity interval training participants registering a 15.8% improvement and the multimodal training participants registering the highest benefit at 20.4%, all $p < 0.001$. The parameters of skin elasticity showed the same trends, being 19.1, 16.7, and 22.3% higher in the exercise groups respectively as compared to 2.1% in controls. There were significant improvements of 13.4, 11.7, and 16.2 in the exercise groups of transepidermal water loss compared to the sedentary controls of 2.9, respectively. (Table 2).

Parameter	Sedentary Controls (n=85)	Moderate Cardiovascular (n=88)	HIIT (n=86)	Multimodal Training (n=85)	p-value*
Skin Hydration (AU)					
Baseline	41.8 ± 9.2	42.4 ± 8.9	42.1 ± 9.1	42.6 ± 8.7	0.84
12-month	42.6 ± 9.5	49.7 ± 9.8	48.8 ± 9.4	51.3 ± 10.1	<0.001
Change from baseline, %	1.8 (-1.8, 5.4)	17.2 (13.6, 20.8)	15.8 (12.2, 19.4)	20.4 (16.8, 24.0)	<0.001
p-value vs control	—	<0.001	<0.001	<0.001	
Skin Elasticity R2 (%)					
Baseline	67.9 ± 12.8	68.7 ± 11.9	68.4 ± 12.3	68.9 ± 12.1	0.89
12-month	69.3 ± 13.1	81.8 ± 13.4	79.8 ± 12.9	84.3 ± 13.7	<0.001
Change from baseline, %	2.1 (-1.6, 5.8)	19.1 (15.4, 22.8)	16.7 (13.0, 20.4)	22.3 (18.6, 26.0)	<0.001
p-value vs control	—	<0.001	<0.001	<0.001	
TEWL (g/m²/h)					
Baseline	15.1 ± 3.4	14.6 ± 3.2	14.8 ± 3.1	14.7 ± 3.3	0.73

12-month	15.5 ± 3.7	12.6 ± 2.9	13.1 ± 3.0	12.3 ± 2.8	<0.001
Change from baseline, %	2.9 (-0.6, 6.4)	-13.4 (-16.8, -10.0)	-11.7 (-15.1, -8.3)	-16.2 (-19.6, -12.8)	<0.001
p-value vs control	—	<0.001	<0.001	<0.001	

Overall ANOVA p-value; HIIT = high-intensity interval training; AU = arbitrary units; TEWL = transepidermal water loss; Data presented as mean (95% CI) for change from baseline; Negative TEWL change indicates improvement (reduced water loss); mean±SD, n (%)

Table 2: Primary Skin Health Outcomes at 12 Months

3.4. Economic, Productivity, and Healthcare Utilization Outcomes

Physical exercise was linked to large statistically significant decreases in dermatology-associated healthcare use, out-of-pocket spending, productivity loss, and aggregate economic cost relative to sedentary controls (Table 3). The number of visits to the dermatology clinic was significantly reduced in all of the active groups with multimodal training participants averaging 1.7±0.9 visits/person/year as opposed to 3.8±1.4 visits/person/year in the sedentary controls (p<0.001) which is a 55% decrease. The percentage of those who had to be prescribed dermatological drugs was 34.1 in the sedentary controls, 12.5, 16.3 and 9.4 in moderate cardiovascular, HIIT and multimodal training groups respectively (all p<0.001). OTC spending on skincare was also significantly less in active participants with multimodal training participants spending PKR 1,870 +- 680/month compared to PKR 3,420 +- 980 in sedentary controls.

Work productivity impairment declined from 18.4±7.6% in sedentary controls to 9.7±5.2%, 10.9±5.8%, and 7.8±4.6% in moderate cardiovascular, HIIT, and multimodal training groups respectively (all p<0.001). Dermatology-specific quality of life improved substantially, with DLQI scores decreasing from 6.8±3.2 in sedentary controls to 3.9±2.4, 4.2±2.6, and 3.1±2.1 in active groups. Work days lost due to skin-related illness were reduced by 56–66% in active participants compared to sedentary controls. The estimated total annual per-patient dermatology-related cost was PKR 42,600±14,200 in sedentary controls, compared to PKR 22,400±9,800, PKR 25,100±10,400, and PKR 18,700±8,300 in moderate cardiovascular, HIIT, and multimodal training groups respectively, representing estimated annual savings of PKR 17,500 to PKR 23,900 per active participant.

Economic/Healthcare Outcome	Sedentary Controls (n=85)	Moderate Cardiovascular (n=88)	HIIT (n=86)	Multimodal Training (n=85)	p-value
Healthcare Utilization					
Dermatology clinic visits (per person/year)	3.8 ± 1.4	2.1 ± 1.0	2.4 ± 1.1	1.7 ± 0.9	<0.001
Prescription dermatological medication use, n (%)	29 (34.1)	11 (12.5)	14 (16.3)	8 (9.4)	<0.001
OTC skincare expenditure/month, PKR	3,420 ± 980	2,180 ± 740	2,310 ± 790	1,870 ± 680	<0.001

Productivity Outcomes					
Work days lost due to skin-related illness (days/year)	3.2 ± 1.8	1.4 ± 1.1	1.6 ± 1.2	1.1 ± 0.9	<0.001
DLQI score (0–30, lower = better)	6.8 ± 3.2	3.9 ± 2.4	4.2 ± 2.6	3.1 ± 2.1	<0.001
Work productivity impairment, % (WPAI)	18.4 ± 7.6	9.7 ± 5.2	10.9 ± 5.8	7.8 ± 4.6	<0.001
Economic Burden					
Total annual dermatology-related cost per patient, PKR	42,600 ± 14,200	22,400 ± 9,800	25,100 ± 10,400	18,700 ± 8,300	<0.001
Estimated annual cost saving vs sedentary, PKR	Ref	20,200	17,500	23,900	<0.001

DLQI = Dermatology Life Quality Index; WPAI = Work Productivity and Activity Impairment; OTC = over-the-counter; PKR = Pakistani Rupees; HIIT = high-intensity interval training; Data presented as mean±SD or n (%)

Table 3: Economic, Productivity, and Healthcare Utilization Outcomes at 12 Months

3.5. Multiple Linear Regression Analysis

Multiple linear regression analysis demonstrated that exercise group classification was a significant predictor of all primary skin health parameters at 12 months after adjusting for age, sex, baseline BMI, and baseline skin parameters (Tables 3a and 3b). Compared to sedentary controls, multimodal training was associated with the greatest improvements in skin hydration ($\beta=7.93$, 95% CI: 5.68–10.18, $p<0.001$) and skin elasticity ($\beta=15.67$, 95% CI: 12.55–18.79, $p<0.001$). Age was inversely associated with both outcomes, while female sex was positively associated with skin hydration outcomes.

Variable	β Coefficient	95% CI	Standard Error	t-value	p-value
Exercise Groups (ref: Sedentary)					
Moderate Cardiovascular	6.52	4.28 to 8.76	1.14	5.72	<0.001
High-Intensity Interval Training	5.89	3.64 to 8.14	1.15	5.13	<0.001
Multimodal Training	7.93	5.68 to 10.18	1.15	6.90	<0.001
Age (years)	-0.12	-0.18 to -0.06	0.03	-4.00	<0.001
Female sex	1.23	0.15 to 2.31	0.55	2.24	0.026
Baseline BMI (kg/m ²)	-0.18	-0.31 to -0.05	0.07	-2.71	0.007
Baseline skin hydration	0.73	0.68 to 0.78	0.03	24.33	<0.001

$Adjusted R^2 = 0.68, F(8,335) = 47.3, p < 0.001$

Table 3a: Multiple Linear Regression — Model 1: Skin Hydration (AU) as Dependent Variable

Variable	β Coefficient	95% CI	Standard Error	t-value	p-value
Exercise Groups (ref: Sedentary)					
Moderate Cardiovascular	12.84	9.73 to 15.95	1.59	8.08	<0.001
High-Intensity Interval Training	10.92	7.80 to 14.04	1.59	6.87	<0.001
Multimodal Training	15.67	12.55 to 18.79	1.59	9.85	<0.001
Age (years)	-0.28	-0.37 to -0.19	0.05	-5.86	<0.001
Baseline elasticity R2	0.69	0.63 to 0.75	0.03	22.67	<0.001
$Adjusted R^2 = 0.61, F(8,335) = 38.9, p < 0.001$					

Table 3b: Multiple Linear Regression — Model 2: Skin Elasticity R2 (%) as Dependent Variable

3.6. Exercise-Related Adverse Events

Systematic monitoring identified exercise-related skin complications in 13.1% of active participants (34 of 259 exercisers) compared to 3.5% of sedentary controls (Table 4). Acne mechanica was the most common complication, affecting 18 participants (6.9% of exercisers), with highest incidence in multimodal training participants who had greater equipment exposure. Contact dermatitis affected 12 participants (4.6% of exercisers), primarily related to cleaning chemicals in fitness facilities. Exercise-induced urticaria occurred in 5 participants (1.9% of exercisers), predominantly during high-intensity activities in warm environments. No serious adverse events were attributed to exercise participation, and all identified complications were successfully managed with conservative interventions.

Complication Type	Sedentary Controls (n=85)	Moderate Cardiovascular (n=88)	HIIT (n=86)	Multimodal Training (n=85)	Total Exercise Groups (n=259)
Acne Mechanica	0 (0%)	3 (3.4%)	2 (2.3%)	13 (15.3%)	18 (6.9%)
Contact Dermatitis	1 (1.2%)	2 (2.3%)	1 (1.2%)	9 (10.6%)	12 (4.6%)
Exercise-Induced Urticaria	0 (0%)	1 (1.1%)	3 (3.5%)	1 (1.2%)	5 (1.9%)
Friction Injuries	0 (0%)	2 (2.3%)	1 (1.2%)	1 (1.2%)	4 (1.5%)
Total Participants with ≥ 1	3 (3.5%)	8 (9.1%)	6 (7.0%)	20 (23.5%)	34 (13.1%)

Complication					
<i>HIIT = high-intensity interval training; Data presented as n (%)</i>					

Table 4: Exercise-Related Skin Complications by Group

4. DISCUSSION

This twelve-month prospective cohort study demonstrates that consistent physical activity produces substantial, sustained improvements in skin health parameters alongside meaningful reductions in dermatology-related economic burden, healthcare utilization, and productivity impairment. The 15–22% improvements in skin hydration, elasticity, and barrier function represent clinically meaningful changes comparable to those achieved through pharmacological interventions.^{18–19} Multimodal training combining cardiovascular and resistance exercise showed superior benefits compared to single-modality approaches, consistent with previous research on combined exercise and supplementation effects.^{20–21}

The observed biophysical benefits likely result from multiple synergistic mechanisms. Improvements in microcirculation and nutrient delivery to cutaneous tissues are achieved by cardiovascular exercise and resistance training stimulates the release of growth hormone and collagen synthesis, respectively.^{16–13} These physiological effects are consistent with the existing state of knowledge about the effects of physical activity on skin health and condition.³

The economic and productivity findings are particularly significant because they add to the clinical value of the study, beyond the biological effects. The exercise group had 44-56% fewer dermatology clinic visits, 37-73% fewer prescription medications, and an estimated (monetary) value of PKR 17,500 to PKR 23,900 in per-patient, annual savings compared to the sedentary controls. These values are low because they do not take into account more important economic benefits such as a reduced number of emergency visits, cosmetic procedures or long-term reduction in the cost of chronic skin disease. Exercise groups had a 40-58% reduction in work productivity impairment with similar results in the improvement of DLQI scores that prove increased health-related quality of life. The mechanism of the increased skin barrier activity and decreased treatment seeking behavior is mechanistically feasible: with decreasing TEWL and hydration, the discomfort and visible symptomatology of most dermatological issues becomes less intense, which lessens the urge to consult and take medicine. The implications of these findings on healthcare policy are significant because they indicate that the downstream savings in the expenditure on dermatology care can be substantial in case the investments in structured physical activity programs are made.¹⁴

We found superior skin parameter improvements of 1522 percent relative to other cross-sectional studies (812 percent) and we were the first to combine intervention outcomes of economic and productivity with biophysical endpoints, which lends credibility to the safety of moderate to vigorous exercise on dermatological health.¹¹

5. Study Strengths

The strengths of the study include the prospective longitudinal design with 12-month follow-up, large sample size with high retention (89.4%) and objective measurement techniques using validated instruments,^{7–9} thorough exercise verification using several measures, multiple confounders are considered, and the novel introduction of

economic, productivity and health-care utilisation outcomes. Recruitment from different sources improves population representativeness.

6. Limitations

The observational approach has lower levels of inference than a randomized trial. Lack of blinding may have contributed to bias. The cost analysis used self-reported data on costs, which may be subject to recall bias. The healthy and educated population may limit the generalizability of results to those with skin disease or lower socioeconomic status. Cost data are limited to the Pakistani health-care system and may not be applicable elsewhere.

7. Future Research and Recommendations

Randomized controlled trials of exercise effects in specific skin diseases, such as psoriasis and atopic dermatitis, which have compromised barrier structure, are needed.¹² Cost-effectiveness and quality-adjusted life year (QALY) calculations would allow more accurate estimates for policy purposes. Mechanistic studies examining cellular pathways would help understand the benefits.²²

Health-care practitioners should endorse multimodal exercise programs (150-300 minutes per week cardiovascular exercise and resistance training) to improve skin health and consider financial implications when advising patients. Skin health associations and health insurance companies should consider subsidizing exercise programs as part of skin health care. Patients should be counselled about prevention of complications through hygiene and equipment care.¹² The promise of AI-based, personalized exercise prescriptions is an emerging opportunity for individualized skin health improvement.²⁴⁻²⁵

8. CONCLUSION

The present study shows that regular engagement in physical activity leads to significant and long-lasting skin health improvements over 12 months, while also generating important reductions in dermatology-related health care use, out-of-pocket costs and workplace productivity loss. Combined cardiovascular and resistance exercise training offers the greatest improvements in all clinical and economic outcomes. Side effects of exercise are minimal. This research supports exercise as a cost-effective, first-line treatment to improve skin health and offers robust evidence for the incorporation of exercise advice into dermatological care. The size of the clinical and economic benefits present in this study suggests exercise is effective as an anti-aging and health promotion strategy that has particular relevance among middle-aged adults and has important implications for health-care resource allocation.

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