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ORIGINAL

Impact of physical activity and body composition on cardio-vascular health post-COVID-19 in Guayaquil

Impacto de la actividad física y la composición corporal en la salud cardiovascular post-COVID-19 en Guayaquil

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ABSTRACT

The COVID-19 pandemic has left persistent health consequences among survivors, particularly cardiovascular complications. In this context, understanding the role of physical activity and body composition in recovery is crucial. This study aimed to analyze the impact of physical activity and body composition on cardiovascular health in COVID-19 survivors in Guayaquil, Ecuador. A cross-sectional, quantitative, and multivariate study was conducted with a sample of 200 health sciences students who had recovered from COVID-19. Data were collected through validated questionnaires and anthropometric measurements, including BMI, body fat percentage, and blood pressure. Statistical analyses included Principal Component Analysis (PCA) and K-means clustering to identify latent patterns and subgroups. The results showed that higher frequency and intensity of physical activity were significantly associated with better cardiovascular indicators and improved post-COVID-19 recovery. Individuals with unfavorable body composition, particularly high body fat, had increased cardiovascular risk. PCA identified two main components explaining 78,2 % of the variance, while K-means revealed three distinct health profiles among participants. In conclusion, physical activity and body composition are critical factors influencing cardiovascular health in post-COVID-19 individuals. The findings highlight the need for tailored intervention strategies focused on promoting active lifestyles and body composition control to improve long-term cardiovascular outcomes. These insights are particularly relevant for vulnerable urban populations in Latin America.

Keywords: Physical Activity; Body Composition; Cardiovascular Health; Principal Component Analysis; Biplot; K-Means.

RESUMEN

La pandemia de COVID-19 ha dejado consecuencias persistentes en la salud de los sobrevivientes, especialmente complicaciones cardiovasculares. En este contexto, comprender el papel de la actividad física y la composición corporal en la recuperación resulta fundamental. Este estudio tuvo como objetivo analizar el impacto de la actividad física y la composición corporal sobre la salud cardiovascular en personas que superaron el COVID-19 en Guayaquil, Ecuador. Se realizó un estudio cuantitativo, transversal y multivariado con una muestra de 200 estudiantes de ciencias de la salud que habían superado la enfermedad. Se recolectaron datos mediante cuestionarios validados y mediciones antropométricas, incluyendo el índice de masa corporal (IMC), porcentaje de grasa corporal y presión arterial. Los análisis estadísticos incluyeron el Análisis de Componentes Principales (ACP) y el algoritmo de agrupamiento K-means para identificar patrones

latentes y subgrupos. Los resultados mostraron que una mayor frecuencia e intensidad de actividad física se asociaron significativamente con mejores indicadores cardiovasculares y una recuperación post-COVID-19 más favorable. Las personas con una composición corporal desfavorable, especialmente con alto porcentaje de grasa, presentaron un mayor riesgo cardiovascular. El ACP identificó dos componentes principales que explicaron el 78,2 % de la varianza, mientras que K-means reveló tres perfiles de salud distintos entre los participantes. En conclusión, la actividad física y la composición corporal son factores clave que influyen en la salud cardiovascular en personas post-COVID-19. Los hallazgos destacan la necesidad de implementar estrategias de intervención personalizadas enfocadas en promover estilos de vida activos y el control de la composición corporal, especialmente en poblaciones urbanas vulnerables de América Latina.

Palabras clave: Actividad Física; Composición Corporal; Salud Cardiovascular; Análisis de Componentes Principales; Biplot; K-means.

INTRODUCTION

The COVID-19 pandemic has profoundly affected global health due to its high rates of infection, mortality, and the chronic consequences faced by survivors.[1] Among these, cardiovascular complications are among the most concerning, as they may persist beyond the acute phase of the illness and can be aggravated by a lack of physical activity and unfavorable body composition.[2] This reality emphasizes the importance of identifying modifiable factors that could support recovery and prevent long-term deterioration of cardiovascular health.

Physical activity and healthy body composition are globally recognized as key factors for promoting cardiovascular health and overall well-being.[3] These elements have been central to global health guidelines for decades. However, the specific consequences for individuals who have recovered from COVID-19 remain underexplored, especially in cities with unique demographic and environmental characteristics such as Guayaquil, Ecuador.[4,5] This city was one of the most severely impacted in the country, making it a relevant context for analyzing these health-related factors.[6]

Research indicates that SARS-CoV-2 can negatively affect the cardiovascular system by causing myocardial injury, arrhythmias, thrombotic events, and endothelial dysfunction.[7,8,9,10] These issues can persist long after the infection resolves, even in patients who were not hospitalized.[11] Consequently, post-COVID-19 care must prioritize cardiovascular monitoring and rehabilitation,[12] particularly in socioeconomically vulnerable populations.

Regular physical activity has been shown to improve heart function, lower blood pressure, and reduce the risk of cardiovascular disease, making it essential for long-term recovery in COVID-19 survivors.[13,14,15,16,17,18] Additionally, physical activity can mitigate stress and anxiety, common psychological consequences of the disease.[19]

Body composition is also a critical factor. Excess adipose tissue, particularly visceral fat, is associated with a higher risk of heart disease and stroke,[20,21] while greater muscle mass supports better cardiovascular function and physical performance.[22] The interplay between physical activity, body composition, and cardiovascular health is further shaped by genetics, diet, and lifestyle factors.[23,24]

Recent studies underscore the critical role of structured physical activity and body composition in cardiovascular outcomes post-COVID-19. Jimeno-Almazán et al.[25] demonstrated that supervised exercise significantly improves cardiovascular and mental health in recovered patients. Similarly, Bhakaney et al.[26] reported enhancements in functional capacity and emotional well-being through physical activity programs. Lemos et al.[27] found that excess adiposity and reduced muscle mass were directly associated with persistent symptoms and impaired cardiovascular function.

Despite this growing body of evidence, Latin American contexts remain underrepresented in the literature. Urban areas with high vulnerability—like Guayaquil—face challenges such as limited access to rehabilitation and persistent socioeconomic inequality.[28,29] Understanding these local dynamics is essential for developing effective and context-specific public health interventions.

Considering this, the central research question guiding this study is: To what extent do physical activity and body composition influence cardiovascular health in post-COVID-19 individuals in Guayaquil?

The main objective of this study is to analyze the impact of physical activity and body composition on cardiovascular health in COVID-19 survivors in Guayaquil. Specifically, it seeks to:

- Evaluate the association between the frequency and intensity of physical activity and cardiovascular indicators.
- Examine the relationship between body composition and cardiovascular risk.
- Identify distinct cardiovascular health profiles among post-COVID-19 individuals using multivariate analysis.

METHOD

The study used a quantitative, observational, and cross-sectional approach to test the proposed theory and present a statistical representation of the research data.[30] A total of 200 health sciences students from Milagro State University, all of whom had recovered from COVID-19, participated in the study. Anthropometric measurements—such as Body Mass Index (BMI), body fat percentage, and blood pressure—were taken to evaluate cardiovascular health indicators. Additionally, physical activity levels were assessed using validated questionnaires. The data were analyzed using multivariate statistical techniques to explore correlations among variables and identify relevant patterns.[31]

Research Design

A descriptive and multivariate quantitative research design was selected because it enables the identification and comparison of cardiovascular health indicators across different groups. This approach is particularly useful for analyzing disparities in blood pressure, physical activity levels, and body composition among health students.[32]

Participants

Students belonging to the Health Sciences field of study at the Milagro State University were chosen through a sampling process that combined finite and stratified population elements. Inclusion criteria required official enrollment in the academic program and belonging to one of the educational levels. Students who did not meet these formal enrollment requirements were excluded from the study.

To determine the appropriate sample size, we applied a finite population formula using the total population of 1250 health science students. The sample size was calculated with a 95 % confidence level and a 2,5 % margin of error. Assuming a response distribution of 50 % (p = 0,5) to maximize variability, the following formula was applied:

The formula for determining the sample size[33] was equation 1:

$$n = \frac{N * Z^2 * p * (1 - p)}{e^2 * (N - 1) + Z^2 * p * (1 - p)} \qquad (1)$$

Where:

n is the sample size.

N is the population size.

Z is the Z-score for the confidence level (1,96 for 95 %).

p is the estimated proportion of the population with the characteristic of interest (assumed to be 0,5 for maximum variability).

e is the margin of error (0,025).

The result indicated a minimum sample size of approximately 196 participants. To account for potential non-response or incomplete data, a final sample of 200 students was selected.

Data Collection Instrument

A questionnaire was applied to a random sample of 200 students, to establish a conceptual model for the study.[12] The model presented the expected congruence between the observed variables and the structure.[12]

Questionnaire Structure and Variables Included in the PCA

The questionnaire applied in this study comprised 25 items grouped into six dimensions, each measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). These dimensions were adapted from the validated instrument developed by Lacomba-Trejo et al.[34] and tailored to evaluate the relationship between physical activity, body composition, and cardiovascular health in post-COVID-19 university students. The items were designed to capture both objective perceptions and subjective health indicators and each dimension was used as a composite variable in the Principal Component Analysis (PCA). This analysis enabled the identification of latent structures and interrelationships among physical activity, body composition, and cardiovascular health in the studied population.

A detailed list of all questionnaire items by dimension is provided in appendix A.

Frequency and Type of Physical Activity (Items 1–5): this dimension included items evaluating the regularity of physical activity, participation in recreational activities, preference for outdoor versus indoor settings, and variety in the types of physical activity performed.

Intensity of Physical Activity (Items 6–10): Items in this group assessed the physiological responses to exercise such as increased respiration and heart rate, sweating, perceived exertion, and effort to exceed physical limits.

Body Composition (Items 11–14): focused on self-perceptions regarding weight, muscle mass, nutritional habits, and the balance between fat and muscle mass.

Cardiovascular Health (Items 15–18): included self-reported indicators such as medical checkups, physical endurance, absence of cardiac discomfort during exercise, and normal levels of blood pressure and cholesterol.

Post-COVID-19 Recovery (Items 19–21): these items measured the perceived return to normal physical activity, respiratory capacity, and physical energy levels after COVID-19 recovery.

Health-Related Quality of Life (Items 22–25): addressed general health satisfaction, energy for daily tasks, mental and emotional well-being, and perceived quality of life improvements linked to healthy habits.

Data Collection Procedure

The questionnaire used in the research was based on the instrument created and validated by Lacomba-Trejo et al.[34] This original questionnaire was structured to measure the level of vulnerability of adolescents to the pandemic and its important psychological impact. It is important to detect which factors function as a risk and which as protection against COVID-)]. The methodology used to develop the questionnaire included consulting experts to define the factors, draft the questions, and calculate a uniqueness index.

Data Analysis

The collected data were analyzed using Jamovi, a statistical software. To assess differences between groups, specific statistical tests were used, Principal Component Analysis (PCA) was carried out to identify the fundamental dimensions that explain most of the variability in the data on the influence of physical activity and body composition on the cardiovascular health of COVID-19 survivors in Guayaquil the Biplot is a graphical tool that enables the joint visualization of variables and observations within the space defined by the principal components.[35]

Arrows symbolize variables, visualizations illustrate the projection of the original variables into the space defined by the principal components.[36] Dots symbolize observations made (people who survived COVID-19). The tests were chosen for their ability to compare groups and analyze the correlation between variables.[37]

Latent Factor Extraction and Variable Contribution

The dimensions (or latent factors) presented in table 1 and components in table 2 were derived from the aggregation of individual questionnaire items. Each dimension represents a latent construct, composed of several observable variables (items), as detailed in annexes.

To ensure clarity and transparency in the interpretation of the latent factors, we report the following:

- Dimension Construction: Each latent factor was formed by averaging the responses to the individual items corresponding to its theoretical construct. For instance, the dimension "Frequency and Type of Physical Activity" includes items related to weekly frequency, recreational activities, variety of physical exercises, and preference for outdoor activities (Items 1–5). Similar item-level mappings are provided for all six dimensions.
- Factor Extraction Criteria: principal Component Analysis (PCA) was used to identify latent structures underlying the data. Components were retained based on:
    1. Kaiser Criterion: components with eigenvalues greater than 1 were retained.
    2. Cumulative Variance Explained: the first two components explained approximately 78,2 % of the total variance, meeting the threshold for adequate factor representation.
    3. Scree Plot Inspection: the visual elbow observed between the second and third eigenvalues supported the selection of the first two components.

- Variable Contributions to Components: the PCA biplot (figure 1) graphically represents how each observed variable loads onto the extracted components. Arrows in the biplot indicate the direction and strength of each variable's contribution to the principal components. Variables such as "Cardiovascular Health," "Body Composition," and "Health-Related Quality of Life" showed strong loadings on the first principal component (Dim1), while "Intensity of Physical Activity" and "Post-COVID Recovery" aligned more closely with Dim2.

This methodological transparency ensures that the interpretation of the PCA results is grounded in the observable behavior and health perceptions of the respondents.

Ethical Considerations

Informed consent was obtained from all study participants. Data privacy and confidentiality were maintained at all times, under the ethical principles of research.

RESULTS AND DISCUSSION

The Cronbach's Alpha values obtained for all dimensions exceed the commonly accepted threshold of 0,7 (table 1), in-dicating adequate internal consistency of the scales used in the study.

The results of the multivariate analysis revealed significant correlations between BMI, body fat percentage, and blood pressure with physical activity levels. Specifically, the study analyzed the following components: Body Mass Index (BMI), percentage of body fat, muscle mass, systolic and diastolic blood pressure, as well as subdimensions of the phys-ical activity scale (frequency, intensity, and type of activity). Statistical evaluations, including Principal Component Analysis (PCA) and K-means clustering, provided insights into the interrelationships among these variables and al-lowed for the identification of distinct groups with varying cardiovascular risk profiles.

Table 1. Cronbach's alpha α by dimension

Dimensions	Cronbach's alpha
Frequency and Type of Physical Activity	0,8356
Intensity of Physical Activity	0,8623
Body Composition	0,9243
Cardiovascular Health	0,9345
Post-COVID-19 Recovery	0,9178
Health-Related Quality of Life	0,9134

The high Cronbach's alpha values observed across all six dimensions (all > 0,83) indicate a strong internal consistency of the constructs measured by the questionnaire. These elevated scores are likely explained by the following observable factors:

- Conceptual coherence among items: each dimension was constructed using items that measure closely related behaviors or perceptions. For example, the dimension "Intensity of Physical Activity" includes items focused on physiological respons-es (e.g., breathing, heart rate, sweating) which are naturally correlated.
- Homogeneous target population: the sample consisted of health sciences stu-dents with similar levels of knowledge and behavior regarding physical activity and health, which likely contributed to consistent responses across items.
- Clear and concise item formulation: the questionnaire employed straightforward language and concrete examples, reducing the likelihood of misinterpretation and promoting response consistency

Although high alpha values are generally desired, we acknowledge that very high scores (e.g., > 0,9) may occasionally reflect redundancy among items. However, in this study, each item captured a distinct aspect of the latent construct, supporting the multidimensionality and reliability of the scales.

Table 2. Principal Component Analysis: Eigenvalues and Variance Explained

Component	Eigenvalue	% of Variance	Cumulative %
Frequency and Type of Physical Activity	4,103	68,39	68,4
Intensity of Physical Activity	0,592	9,86	78,2
Body Composition	0,501	8,35	86,6
Cardiovascular Health	0,354	5,90	92,5
Post-COVID-19 Recovery	0,283	4,72	97,2
Health-Related Quality of Life	0,167	2,78	100,0

The first two components together explain approximately 78,2 % of the total variance in the data (table 2), indicating that these two axes are critical to understanding disparities in post-COVID-19 cardiovascular health based on physical activity and body composition. The other elements provide more detailed and specific explanations, although their influence is less.

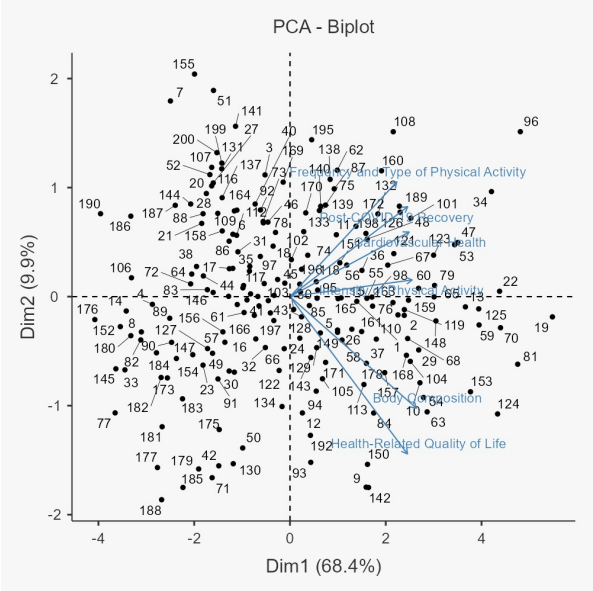

Figure 1. PCA BIPLOT

Figure 1 represents a Principal Component Analysis (PCA) Biplot graph showing the relationship between individuals and variables in a study on the impact of physical activity and body composition on post-COVID-19 cardiovascular health in Guayaquil.

The variables of Health-Related Quality of Life and Body Composition are strongly correlated with the main components (Dim1 and Dim2), indicating that these components explain the variability appropriately. On the other side, the varia-bles Frequency and Type of Activity Physics, Cardiovascular Health, Post-COVID-19 Recovery, and Activity Intensity Physics present a variability that is well explained mostly by the Dim1 component.

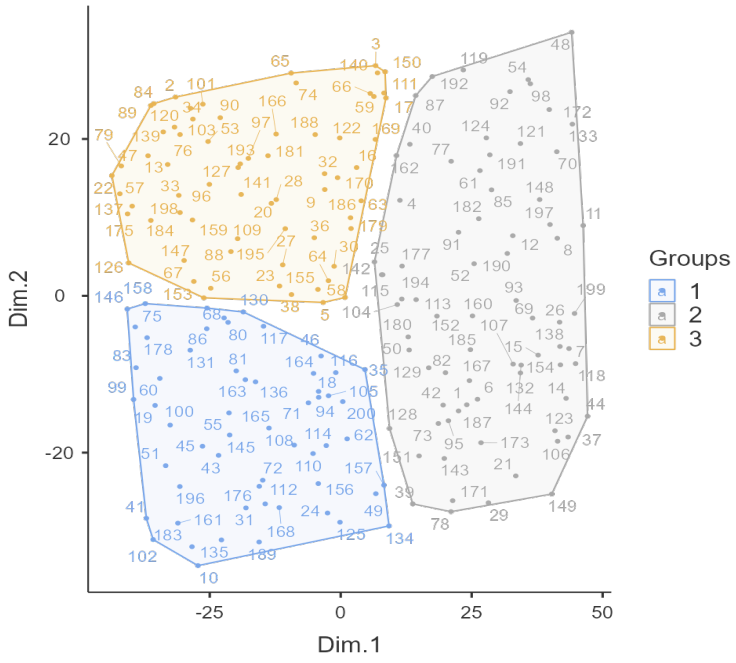

Figure 2. K- means Plot

Furthermore, according to figure 1, there is a strong correlation between Cardiovascular Health and Frequency and Type of Activity Physics, as well as with post-COVID-19 recovery and Activity Intensity Physics, though this last sample an association further strong. On the other side, Body Composition and Health-Related Quality of Life are strongly corre-lated with each other, while both variables present a correlation further weak with the post-COVID-19 recovery.

This representation (PCA- Biplot) is essential for understanding the interaction between these dimensions and

their contribution to cardiovascular health in the post-COVID-19 period. The results indicate that interventions aimed at improving the Frequency and type of Physical Activity and the Intensity of Physical Activity can significantly influence the cardiovascular health and post-COVID-19 recovery. Likewise, improvements in body composition could significantly influence Health-Related Quality of Life.

For the K-means cluster analysis (figure 2), six composite variables were used, corresponding to the six dimensions assessed through the questionnaire and validated with PCA:

1. Frequency and type of physical activity.
2. Intensity of physical activity.
3. Body composition.
4. Cardiovascular health indicators.
5. Post-COVID-19 recovery status.
6. Health-related quality of life.

Each of these dimensions was derived by averaging the Likert-scale responses of the items corresponding to each con-struct. Prior to clustering, the variables were standardized (z-scores) to ensure comparability and avoid scale bias. The number of clusters (k=3) was selected based on interpretability and visual inspection of the within-cluster sum of squares (WCSS) using the elbow method.

Figure 2 shows a K-means clustering diagram that classifies 200 subjects according to the key variables linked to the impact of physical activity and body composition on cardiovascular health after COVID-19 in Guayaquil. The importance of this graph lies in the identification of patterns and segments in the data, which may have significant implications for public health interventions and recovery policies.

Group 1, identified as the Blue Area, is the first group to be considered in the study. The characteristics of this group are located in the lower left region of the graph, where the scores of the dimensions (Dim1 and Dim2) are reduced.

In this group, individuals may present characteristics such as a lower intensity of physical activity, a less favorable body composition, as well as a less favorable post-COVID-19 recovery and poor cardiovascular health. The characteristics of this group are also that they do not have a good body composition, as well as a poor health-related quality of life. The possibility that this group presents unfavorable cardiovascular health and post-COVID-19 recovery outcomes indicates the importance of implementing specific interventions aimed at improving their physical condition and general well-being.

Group 2 belongs to the Orange Area. The characteristics of this group are found in the upper part of the graph, presenting moderate to high values in Dim2 and low values in Dim1.

The interpretation of this group suggests that its members have a favorable body composition as well as a favorable health-related quality of life, although they have little physical activity, a slow post-COVID-19 recovery, and poor cardi-ovascular health.

Cluster 3, also known as the Gray Area. The characteristics of this cluster are seen in its position on the right side of the graph, presenting high scores in Dimension 1 and a greater dispersion in Dimension 2.

The interpretation suggests that this group of people could present a wide range of differences in terms of their level of physical activity and body composition. Some people could enjoy an optimal state of health, while others could be at risk. The dispersion of data indicates the presence of subgroups within the sample that requires specific interventions.

In line with existing research,[13,15,25,27,38] the findings of this study support the growing evidence that regular physical activity and healthy body composition act as protective factors for cardiovascular health in individuals recovering from COVID-19.

A higher frequency and intensity of physical activity were significantly associated with improved cardiovascular indicators, such as lower systolic and diastolic blood pressure, as well as reduced body fat percentage.[39,40,41,42] These results reinforce the study's potential to guide public health interventions and recommendations aimed at improving long-term health outcomes in COVID-19 survivors in Guayaquil and similar regions.[28,29,43]

Scientific literature emphasizes the importance of physical activity in maintaining cardiovascular system health.[13] Consistent with the findings of Jimeno-Almazán et al.[25], supervised exercise programs improve not only physical fitness but also mental health and overall recovery in post-COVID patients. Similarly, Lemos et al.[27] reported that un-favorable body composition—particularly increased fat mass—is associated with lower cardiorespiratory capacity and persistent symptoms such as fatigue and shortness of breath.

This study provides additional evidence regarding the cardiovascular effects of COVID-19.[42] Multiple investigations have reported myocardial damage, arrhythmias, and thrombotic events as common sequelae of the virus,[42] under-scoring the need for continuous monitoring of recovered patients. A key contribution of this research is the application of Principal Component Analysis (PCA) and K-means clustering, which enabled the identification of differentiated health profiles within the sample. Three clusters were distinguished: one with low physical activity and high cardiovascular risk; another with favorable body composition but low physical

activity levels; and a third, heterogeneous group with variable health outcomes. These findings support the relevance of implementing personalized intervention strategies tailored to the specific needs of each population subgroup.

Significant correlations were also identified between cardiovascular health and the frequency and intensity of physical activity, as well as between body composition and health-related quality of life. This suggests that the benefits of physical activity are not solely physiological but also psychological and social. In line with the findings of Bhakaney and Vishnu Vardhan, physical exercise positively impacts emotional well-being and perceived quality of life.

Given the increasing recognition of the long-term sequelae of COVID-19, it is imperative to promote regular physical activity among recovered individuals to strengthen their cardiovascular health.[15] Obesity and abnormal fat distribution, particularly visceral fat, significantly increase the risk of cardiovascular disease,[20] highlighting the importance of assessing body composition as an integral component of post-COVID follow-up.

Understanding the influence of body composition on cardiovascular health is essential for designing effective interventions that facilitate recovery and reduce the risk of future complications.[44] The literature reviewed in this study offers a comprehensive perspective on the complex interaction between COVID-19, physical activity, body composition, and cardiovascular health, laying the groundwork for future research.[45]

Evidence indicates that the virus increases the likelihood of thrombosis and directly affects endothelial cells, potentially leading to chronic vascular dysfunction.[9,44] Moreover, the cardiovascular effects of COVID-19 extend beyond the acute phase, presenting as myocarditis or heart failure even long after recovery.[11,47] This context demands a long-term clinical approach focused on continuous cardiovascular health support and monitoring.[12]

Accordingly, prioritizing physical activity as a key rehabilitation tool for COVID-19 survivors is essential. Such activity contributes to maintaining heart function, lowering blood pressure, and preventing heart disease.[15,16] In settings like Guayaquil, where the virus has had a particularly severe impact, promoting active lifestyles could significantly aid in preventing future complications.

Conversely, physical inactivity is linked to a higher risk of cardiovascular disease.[17] Evidence suggests that regular exercise improves blood flow, enhances cardiac function, and supports general well-being,[18,48] while also alleviating stress and anxiety, common symptoms among COVID-19 survivors.[19]

The relationship between body composition and cardiovascular health has received growing attention.[25] In local contexts such as Guayaquil, it is vital to analyze this correlation among health professionals and students, who play a crucial role in promoting community wellness.[49] Excess fat, especially visceral fat, is associated with higher risks of myocardial infarction and stroke, whereas increased muscle mass is linked to improved cardiovascular health and physical functionality.[21,22]

Factors such as genetics, lifestyle, and metabolic health influence this relationship, with physical activity being a key determinant of a healthier body composition.[23,24] This highlights the need for comprehensive interventions that consider both the immediate and long-term effects of the virus.[50]

Although the findings align with international literature, this study offers a valuable contextual perspective. The sample comprising of health sciences students in Guayaquil reflects an epidemiological setting characterized by socio-economic inequality, post-pandemic psychological stress, and limited access to preventive healthcare services. These local factors may influence cardiovascular outcomes and underscore the importance of conducting context-specific research.

It is important to note that the study's cross-sectional design does not allow for the establishment of causal relationships. Despite the high internal consistency of the instruments used (Cronbach's alpha > 0,8), the reliance on self-reported questionnaires may introduce response bias. Future longitudinal studies are recommended to explore causal pathways and long-term effects of physical activity and body composition on post-COVID recovery.

In summary, these findings highlight the urgent need to develop and implement structured post-COVID rehabilitation programs in Ecuador, incorporating personalized physical activity, nutritional strategies, and continuous monitoring of body composition. Such programs have the potential not only to improve individual health outcomes but also to reduce the long-term burden on healthcare systems.

Limitations of the Method

It is widely accepted in the academic field that there may be biases in the sample selection process and the personal assessment of digital skills. The methodology used in the study did not allow the determination of causal relationships, being limited only to the description and identification of correlations.

CONCLUSIONS

This study contributes to a growing body of knowledge on the long-term health implications of COVID-19 by providing empirical evidence from a specific Latin American context. By focusing on the interplay between physical activity, body composition, and cardiovascular health among COVID-19 survivors in Guayaquil, the research emphasizes the multi-dimensional nature of post-viral recovery.

Rather than viewing recovery solely through a clinical or biomedical lens, our findings advocate for a holistic approach that incorporates lifestyle, psychological well-being, and contextual factors. This perspective is particularly relevant for low- and middle-income urban settings, where healthcare systems are often overburdened and access to rehabilitation programs remains limited.

Beyond its academic relevance, this study calls for a shift in public health strategies—moving from reactive care to pro-active prevention through tailored physical activity and health promotion initiatives. These interventions must be adap-tive, community-specific, and sustained over time to be effective.

Future efforts should prioritize longitudinal and interdisciplinary research to track how behavioral and physiological variables evolve over time in post-COVID populations. Only then can we build evidence-based, equitable, and inclusive recovery models capable of addressing both the visible and latent consequences of the pandemic.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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ANNEXES

Questionnaire Items by Dimension

Dimension	Item Code	Statement
Frequency and Type of Physical Activity	Item_1	I engage in physical activity at least 3 times per week.
	Item_2	I regularly participate in recreational activities such as walking, dancing, or biking.
	Item_3	I perform structured exercises as part of a weekly routine (e.g., gym, guided classes).
	Item_4	I prefer outdoor physical activities to indoor ones.
	Item_5	I engage in different types of physical activity (aerobic, strength, flexibility).
Intensity of Physical Activity	Item_6	During my workouts, I feel that my breathing significantly accelerates.
	Item_7	I usually perform physical activity that noticeably raises my heart rate.
	Item_8	My sweating increases when I exercise.
	Item_9	I consider the effort level of my physical activities to be high.
	Item_10	I push myself to exceed my physical limits when exercising.
Body composition	Item_11	I am satisfied with my current body weight.
	Item_12	I believe I have an adequate percentage of muscle mass.
	Item_13	I maintain a diet that helps me keep a healthy body composition.
	Item_14	I strive to maintain a balance between muscle mass and body fat.
Cardiovascular Health	Item_15	I have regular medical checkups to monitor my cardiovascular health.
	Item_16	I have good physical endurance during long walks or climbing stairs.
	Item_17	I do not experience cardiac discomfort during exercise.
	Item_18	My blood pressure and cholesterol levels are within normal ranges.
Post-COVID-19 Recovery	Item_19	Since I recovered from COVID-19, I have resumed my usual physical activities.
	Item_20	I feel that my respiratory capacity has fully recovered.
	Item_21	My physical energy has normalized since recovering from COVID-19.
Health-Related Quality of Life	Item_22	I am satisfied with my overall health status.
	Item_23	I have enough energy to carry out my daily activities.
	Item_24	I enjoy good mental and emotional health.
	Item_25	I feel that my quality of life has improved thanks to my healthy habits.