AEROBIC CAPACITY AND PULMONARY FUNCTION IN PARALYMPIC INITIATION ATHLETES

CAPACIDAD AERÓBICA Y FUNCIÓN PULMONAR EN DEPORTISTAS PARALÍMPICOS DE INICIACIÓN

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Short title:
Cardiorespiratory Variables in Paralympic Initiation Athletes

How to cite this article:
Hincapié Gallón, O. L., Tierradentro, L.M., & Rivera Motta, J.A. (2025). Aerobic capacity and pulmonary function in paralympic initiation athletes. *Cultura, Ciencia y Deporte*, *21*(67), 2424. https://doi.org/10.12800/ccd.v21i67.2424

Received: 11 February 2025 / **Accepted:** 11 September 2025

Abstract

The comprehensive assessment of people with disabilities in the process of sports initiation is of significant value and should be evidenced to facilitate the achievement of high-performance practice while preserving health. To identify the status of cardiopulmonary variables, aerobic capacity, and pulmonary function, by considering sociodemographic and clinical variables. A descriptive correlational study was conducted including 23 initiation athletes with physical disabilities. The study involved the characterization of the population and the measurement of Forced Vital Capacity, Forced Expiratory Volume in the first second, ratio of Forced Expiratory Volume in the first second to Forced Vital Capacity, Maximum Voluntary Ventilation, and Slow Vital Capacity from which inspiratory capacity (IC) was obtained, using spirometry with an EasyOne nnd. Oxygen consumption variables were assessed through the YO-YO Test for wheelchair users. There is a statistically significant difference between anthropometric variables and pulmonary function, but no correlations were found with aerobic capacity. Paralympic initiation athletes present with elevated body composition and pulmonary function within normal parameters. The importance of comprehensive and individualized assessments to optimize performance is emphasized.

Keywords: Pulmonary function, paralympic athletes, sports initiation, physical disabilities, oxygen consumption.

Resumen

La valoración integral de personas con discapacidad en proceso de iniciación deportiva es de valor significativo y requiere ser evidenciado para facilitar la práctica el objetivo del alto rendimiento, garantizando la salud. Reconocer el estado de variables cardiopulmonares, capacidad aeróbica y función pulmonar considerando variables sociodemográficas y clínicas. Estudio descriptivo correlacional. Incluyó 23 deportistas de iniciación, con discapacidad física, caracterización de la población, la medición de la Capacidad Vital Forzada, Volumen Espiratorio Forzado en el primer segundo, relación de Volumen Espiratorio Forzado en el primer segundo y Capacidad Vital Forzada, Ventilación Voluntaria Máxima, Capacidad Vital Lenta de la cual se tomó capacidad inspiratoria (IC) a través de espirometría con EasyOne nnd, para las variables del consumo de oxígeno por medio de la prueba de campo YOYO Test para usuarios de silla de ruedas. Existe una diferencia estadísticamente significativa entre variables antropométricas y función pulmonar, pero no se encontraron correlaciones con la capacidad aeróbica. Los deportistas paralímpicos de iniciación presentan una composición corporal elevada y función pulmonar dentro de los parámetros normales. Se resalta la importancia de evaluaciones integrales e individualizadas para optimizar el rendimiento.

Palabras clave: Función pulmonar, atletas paralímpicos, iniciación deportiva, discapacidad física, consumo de oxígeno.

Introduction

The participation of people with disabilities in sports is increasingly recognised in Latin America, as reflected in the number of medals obtained at the Paris 2024 Paralympics (172), compared to the Tokyo 2020 Paralympics (154), thus recognising the increase in medal counts specifically in countries such as Brazil, which increased from 72 medals in Tokyo to 89 in Paris. Similar cases occurred in Colombia, which won 28 medals in Paris, and in Costa Rica and Argentina, which each won two gold medals. Meanwhile, Chile and Mexico changed their positions in the rankings, which did not generally affect Latin America's overall representation in major international competitions.

Furthermore, advances in research in this field have become evident. This is reflected in the increase in publications between 2020 and 2024, where various studies highlight the importance of investigating the assessment of different physical qualities, particularly in sports such as wheelchair basketball (Romarate, et al., 2020; Romarate et al., 2023). In addition, countries such as Spain, Brazil, and Turkey promote the visibility of these advances, as demonstrated in exploratory reviews of specific sports such as para-powerlifting (Puce et al., 2022), which aim to identify training approaches tailored to this sport.

In Colombia, studies such as the one published by Quilindo et al. (2024) highlight the importance of training athletes based on scientific evidence, which enables well-founded approaches aligned with individual needs. As a result, several universities have developed projects focused on adapted and/or Paralympic sports, which generates a positive impact on people with disabilities, establishing sport as one of the strategies that facilitate social inclusion.

In this sense, conducting research involving people with disabilities in the process of sports initiation has a significant impact, as it allows for the identification of the conditions under which they approach different sports. The results of the present study enabled the identification of cardiopulmonary characteristics relevant to the development of sports such as wheelchair tennis, para-powerlifting, para-swimming, and wheelchair basketball. These findings evidenced the status of aerobic capacity and pulmonary function, which are essential for ensuring the development of endurance-related qualities, as well as certain clinical and anthropometric characteristics. These insights facilitate the development of those qualities in the athletes towards high-performance, while considering healthcare as a facilitating factor for long-term sports practice.

For this reason, it is necessary to frame within sports the concepts of the variables considered in this article. In this regard, aerobic capacity in Paralympic sports, although performance in most disciplines is carried out in a seated position and relies primarily on the upper limbs, requires a high demand of aerobic energy over prolonged periods. This is a determining performance variable, as it is an indicator of the athlete's metabolic needs at a specific moment. On the other hand, pulmonary function is a variable related to lung performance, encompassing different components aimed at clearly identifying the functions related to the gas exchange process known as respiration. This process depends on the amount of air the lungs can contain, the gas exchange process, the volume of air that can be moved into and out of the lungs, and the speed at which this can be achieved (Arboleda Amórtegu et al., 2022). This information becomes relevant when considering clinical variables and anthropometric conditions, as it allows for an individualized view of Paralympic athletes.

Aspects related to body composition are a well-studied topic, and its importance is widely acknowledged, along with the benefits of addressing them (Flueck, 2020). This also applies to the population with disabilities, given that changes in body composition such as an increase in body fat percentage and a loss of muscle mass have been reported in this group (Cavedon et al., 2020). For this reason, comprehensive assessments and high-performance oriented approaches are required, which demands the identification of sport-specific variables and intrinsic factors of Paralympic athletes to make individualized adjustments.

Considering the above, despite the increased participation and visibility of Paralympic sports worldwide, especially in Latin America, over the years, there remains a gap in research that integrates the physiological variables necessary for the development of sports. The present study focuses on this issue by investigating the relationship between aerobic capacity, pulmonary function, and body composition in people with disabilities who are involved in sports initiation processes.

Most of the research focuses on individual sports or on high-performance athletes, resulting in limited evidence that relates these variables to populations in the early stages of sports practice. This evidence is essential for designing training, injury prevention, and rehabilitation programs that are better suited to the individual needs of Paralympic initiation athletes.

Finally, the present study aims to relate aerobic capacity and pulmonary function to body composition.

Materials and Methods

Participants

A cross-sectional descriptive study with a correlational stage was conducted with 23 athletes from wheelchair basketball, para-powerlifting, wheelchair tennis, and para-swimming who met the inclusion criteria, such as belonging to sports initiation groups, having physical disabilities, and signing the informed consent form. Conversely, athletes with cardiorespiratory and/or cardiopulmonary diseases, and those who were poorly adapted to their prosthesis, wheelchair, or other mobility device, were excluded from the study.

Instruments

Information was collected using a sociodemographic characterisation form, which included age, gender, type of injury causing the disability, and socioeconomic status. Body composition was assessed by measuring body mass using a SECA Robusta 813 scale, which was calibrated with a wide platform for athletes who were unable to adopt a standing position. The height of the participants was measured using a stadiometer and skinfold thickness was assessed using a Harpenden calliper. Pulmonary function variables were obtained through simple spirometry, while aerobic capacity was assessed using the Yo-Yo Test, which has an ICC of .94, indicating high inter-rater reliability in the measurement of this test.

Procedures

In this study, simple spirometry was performed using computer-based software (Easy on-PC) to determine Forced Vital Capacity (FVC), Forced Expiratory Volume in the first second (FEV1), the ratio of Forced Expiratory Volume in the first second to Forced Vital Capacity (FEV1/FVC), Maximum Voluntary Ventilation (MVV), and Slow Vital Capacity (SVC). This test was performed in a seated position, with a mouthpiece and nose clip in place, instructing the subject to perform a maximal inhalation followed by an explosive and sustained exhalation (Benítez-Pérez et al., 2019).

Aerobic capacity was assessed using the field-based YO-YO Test, following the version previously described by Yanci et al. (2015), in which athletes were required to cover a distance of 10 metres forward and another 10 metres back with running speed paced by a pre-programed audio system that reduced the time between each signal. The test was considered complete when the individual failed to reach the corresponding line on two consecutive occasions or if the participant themselves considered that they could not continue the test due to fatigue. Subsequently, the distance covered by the athlete was measured, their subjective perception of effort at the end of the test was assessed, and their heart rate was monitored during the test using a Polar H10 heart rate monitor placed at the sternal region. Finally, the total distance covered was taken and applied to the formula proposed by Bangsbo et al. (2008) and Krustrup et al. (2003): VO2Max (ml/kg/min) = Distance (m) * 0.0084 + 36.4.

Anthropometric measurements were taken by the same assessor certified by the International Society for the Advancement of Kinanthropometry (ISAK), following its recommendations to minimize measurement bias. The measurements included body mass (kg). Four skinfold measurements were taken with a skinfold calliper (biceps, triceps, subscapular, and suprailiac). The sum of these four skinfold measurements was used to determine body fat percentage through the Durnin and Womersley equation (1974). Fat mass was calculated using mass (kg) * body fat percentage / 100; fat-free mass was calculated using mass (kg) – fat mass (kg); and finally, the fat mass index was calculated using fat mass (kg)/height squared (m2).

Statistical Analysis

The statistical analysis was conducted using IBM SPSS Statistics software. Frequency analysis was applied to categorical variables, while measures of central tendency (mean and standard deviation) were used for numerical variables with normal distribution according to the Shapiro-Wilk test. The median and interquartile range were used for the remaining variables. Pearson's correlation coefficient test was performed for the correlation analysis, with significance levels set at .01 and .05.

Ethic Aspects

This research is part of the institutional macro-project entitled "Cardiopulmonary function in Paralympic initiation athletes in wheelchair basketball, para-powerlifting, wheelchair tennis, and para-swimming," which was approved by the Ethics Committee of the Institución Universitaria Escuela Nacional del Deporte (memorandum No. 40.07.247). In accordance with Resolution 008430 of 1993 of the Colombian Ministry of Health, this research is classified as risk-free, as it employs retrospective documentary research methods and does not involve any intentional intervention or modification of biological, physiological, psychological, or social variables. All information obtained will be treated with strict confidentiality, as stipulated in Articles 1 and 14 of Resolution 1995 of July 8, 1999, of the Colombian Ministry of Health. All data obtained will be used exclusively for research purposes and collected in standardized forms.

Results

Data were collected from 23 Paralympic athletes participating in sports initiation processes, with a median age of 29 years, of whom 56.5% were male. The most frequent cause of disability was spinal cord injury at the T5-T8 vertebral level (34.8%), followed by spinal cord injuries at C1-C7 and T1-T4, both at 21.7%. Para-powerlifting was the preferred sport for most athletes during the initiation process (47.8%) (Table 1).

Table 1

Sociodemographic, Clinical, and Sports-Related Variables of Paralympic Initiation Athletes

Variables	*n*	%
Gender		
Male	13	56.5
Female	10	43.5
Type of injury		
SCI C1-C7	5	21.7
SCI T1-T4	5	21.7
SCI T5-T8	8	34.8
SCI L1-L5	1	4.3
TT amputation	2	8.6
TF amputation	1	4.3
Spastic diplegia	1	4.3
Sport discipline		
Para-swimming	5	21.7
Para-powerlifting	11	47.8
Wheelchair basketball	4	17.4
Wheelchair tennis	3	13
Age (years)*	29(20-62)	

Note. *Variable expressed as Median (IQR). SCI C1-C7: Spinal cord injury at cervical levels 1 to 7. SCI T1-T4: Spinal cord injury at thoracic levels 1 to 4. SCI T5-T8: Spinal cord injury at thoracic levels 5 to 8. TT: Transtibial. TF: Transfemoral.

Regarding the anthropometric variables of Paralympic initiation athletes, a mean Body Mass Index (BMI) of 23.51 kg/m2 was found, which is consistent with the normal range. The mean body fat percentage was 29.03%, thus classifying the sample within the overweight range (Table 2).

Table 2

Anthropometric Variables of Paralympic Initiation Athletes

Anthropometric Variables	Mean ± SD
Body mass (kg)	64.93 ± 15.1
Sitting height (cm)	82.74 ± 4.9
Arm span (m)	1.66 ± 0.1
BMI (kg/m2)	23.51 ± 6.02
Body fat percentage (%)	29.03 ± 8.04
Fat mass (kg)	19.58 ± 8.8
Fat mass index (kg/m2)	7.16 ± 3.44
Fat-free mass (kg)	45.35 ± 7.9

Note. *SD*: Standard Deviation.

Pulmonary function values in Paralympic initiation athletes for FVC, FEV1, the FEV1/FVC ratio, and IC were within the established normal ranges, all above 80%. The mean aerobic capacity was 38.8 ml/kg/min (Table 3).

Table 3

Pulmonary Function Variables and Estimated Aerobic Capacity of Paralympic Initiation Athletes

Variables	Mean ± SD
Pulmonary function	
FVC (%)	81.6 ± 10.4
FEV1 (%)	84.5 ± 8.5
FEV1/FVC (%)	87.14 ± 8.3
IC (%)	82.4 ± 15.9
MVV (L/min)	93.4 ± 20.5
Aerobic capacity	
Estimated oxygen consumption (ml/kg/min)	38.8 ± 1.9

Note. *SD*: Standard Deviation. FVC: Forced Vital Capacity, FEV1: Forced Expiratory Volume in the first second, FEV1/FVC: Ratio of Forced Expiratory Volume in the first second to Forced Vital Capacity, IC: Inspiratory Capacity, MVV: Maximum Voluntary Ventilation.

Table 4 presents the correlations between anthropometric variables and pulmonary function. A significant positive correlation with a weak trend was observed, except for body fat percentage and maximum voluntary ventilation, where a correlation of r = .481 was identified.

Table 4

Correlations Between Anthropometric Variables and Pulmonary Function

Variables	r
Body fat percentage/IC	.576*
Body fat percentage /MVV	.481*
BMI/FVC	.534*
BMI/FV1.FVC	.558*
Body mass/FVC	.550*
Body mass/FEV1.FVC	.599*

Note. *Significant correlation at the .01 level. **Significant correlation at the .05 level. FVC: Forced Vital Capacity, FEV1: Forced Expiratory Volume in the first second, FEV1/FVC: Ratio of Forced Expiratory Volume in the first second to Forced Vital Capacity, IC: Inspiratory Capacity, MVV: Maximum Voluntary Ventilation.

Discussion

The volume of literature on physiological testing in the field of wheelchair sports during the initiation process is considerably smaller compared to that available for individual and team sports without disability, highlighting the value of the present study's findings, which contribute to future processes and/or projects aimed at high-performance development.

Regarding sociodemographic and clinical variables, a constant was found in relation to gender, which is currently a recurring issue, giving rise to the need to encourage greater female participation in sports from the initiation process. However, in the present study, the difference is relatively small, with 13 males and 10 females participating, which is a valuable advance. On the contrary, various studies, such as the one conducted by Yanci et al. (2015), reported a higher percentage of male participants, given that of the 16 participants included in the study, two were female. Similarly, the study conducted by Soylu et al. (2021) shows the participation of 24 males and two females.

On the other hand, the median age of the population in the present study was 29 years, similar to that reported in various recent investigations, with a wide range of ages. For example, Di Gioia et al. (2024) included athletes ranging from 16 to 61 years, with a mean age of 33.2 years, which highlights that in Paralympic sports, particularly during initiation processes, athletes' age will depend on aspects such as the onset of injury, especially in cases of traumatic origin. Therefore, these initiation processes do not always occur early in the life cycle, as is the case in non-disabled sports.

In terms of anthropometric variables, the athletes presented a mean body fat percentage of 29.03%, placing them in the overweight range. In contrast, Di Gioia et al. (2024) study reported a mean of 20.9%, which is within a healthy range. Similarly, Herrera-Amante et al. (2021) found that young swimmers presented a mean body fat percentage of 22.4%. These findings are related to the proven fact that prolonged and regular wheelchair use, both in sports and daily life, is associated with improved body composition adaptations in people with physical disabilities (Cavedon et al., 2020). Taking the above into account, it is evident that athletes in initiation processes do not yet achieve these benefits of sport, such as a reduction in fat mass, as they are not yet currently engaged in high-performance training.

In terms of aerobic capacity, Cherif et al. (2022) found that high-performance Paralympic athletes achieved a median maximum oxygen consumption of 43.33 ml/kg/min, 44.20 ml/kg/min, and 43.19 ml/kg/min in cases of cerebral palsy, amputation, and short stature, respectively. This is comparable to the participants in the present study, as they are people with disabilities who are engaged in initiation sports processes. That is, they have not yet developed the necessary physiological adaptations, as evidenced by the slightly lower values obtained. However, it should be noted that longer periods of sports practice allow greater benefits to be obtained from exercise and training, in this case in terms of oxygen consumption (Giacobbi et al., 2008).

The results of the values established in athletes can be explained by the daily needs of wheelchair use for mobility, forcing the population to cover various distances to accomplish activities of daily living. This finding establishes a positive precedent for performance-oriented sports.

In addition, the continuous physical activity involved in wheelchair propulsion increases oxygen demand in the upper limb muscles, which is provided by the cardiovascular system through cardiac output, which transports the necessary oxygen from stroke volume and heart rate to the muscle cells through the blood vessels. This oxygen in the muscle cell is responsible for generating energy by binding to the electron chain in the mitochondria, which translates into better resistance to muscle fatigue, contributing to improved aerobic endurance.

The aforementioned process increases the activity of peripheral chemoreceptors, such as those located at the carotid bifurcation and the aortic arch, which transmit signals to the respiratory centres in the medulla oblongata, including the dorsal and ventral respiratory groups. These centres, in turn, send signals to the respiratory muscles to increase ventilation, thereby improving gas exchange (Ganong et al., 2020), which is evident in this group of athletes, who demonstrated estimated oxygen consumption values comparable to those of some athletes.

In terms of pulmonary function results, mean values were identified within the established normal ranges, with no alterations, regardless of the eligible impairments that could potentially influence pulmonary volumes and capacities (Hincapié-Gallón et al., 2024).

It should be noted that the trend towards normalization of pulmonary function in these athletes may be explained by the high level of activity in the upper limbs generated by the effort, which increases the contractile frequency of the respiratory

musculature, generating cellular-level adaptations related to muscle hypertrophy over time, thus contributing to improved alveolar ventilation and, consequently, more efficient airflow. This enables athletes to maintain or improve their pulmonary volumes and capacities (Hall, 2021), as was observed in the participants of the present study.

Regarding the relationships among the variables in the present study, no correlation was found between aerobic capacity and sociodemographic variables or pulmonary function results among people with disabilities who are involved in initiation sports processes. However, normal values were observed in these cardiopulmonary characteristics, with a tendency to approximate those of athletes without disabilities. The above is related to the findings of Guillen and Mogollón (2018), who describe changes in these variables after training. Therefore, the results of the present research suggest that participation in sports initiation processes may lead to positive changes in cardiopulmonary variables.

Finally, significant correlations were found between the different components of pulmonary function and anthropometric variables, such as body mass. As Barroso (2018) explains, there is a relationship between body mass index and the pulmonary function variable in forced vital capacity and FEV1, suggesting that an increase in body mass may lead to airway limitation, resulting in a reduction in these variables.

Furthermore, evidence indicates that increases in body composition enhance pulmonary function parameters, whereas higher body fat percentage reduces them because the amount of fat mass limits diaphragmatic descent into the abdominal cavity and due to changes in pulmonary compliance (Ogunlana et al., 2021).

The results of the present study demonstrate that, regardless of the type of impairment, the characteristics related to the cardiorespiratory system do not differ substantially from those of individuals without disabilities, which indicates that physical disability should not be assumed to inherently reduce all physical capacities. Moreover, as observed in athletes without disabilities, body composition can influence the results of values related to pulmonary function.

Conclusions

The study demonstrates that the results related to aerobic capacity and pulmonary function in a group of people with disabilities participating in sports initiation processes are within the recognised normal limits, comparable to those of athletes without obstructive or restrictive respiratory conditions. However, when correlations are made, some significant correlations with anthropometric aspects are evident, which suggests that the aspects of value to be considered are the intrinsic factors of para-athletes that impact physical condition.

The results obtained in this study demonstrate that sports initiation athletes present physiological and anthropometric characteristics that evidence adequate initial training, showing functional values within normal ranges and a positive trend that demonstrates the formative processes in Paralympic sports.

In addition, the observed correlation between body composition and pulmonary function highlights the importance of interdisciplinary work in Paralympic sports to achieve the expected results in the medium and long term.

These results underscore the need to promote the assessment of physical and physiological components, as well as body composition, in Paralympic initiation athletes to foster and optimize exercise adaptations and, therefore, increase the performance of Paralympic athletes in the early stages of sport participation.

Ethics Committee Statement

This research is part of the larger institutional project entitled “Cardiopulmonary Function in Para-Athletes in Wheelchair Basketball, Para Powerlifting, Wheelchair Tennis, and Para Swimming,” which has been approved by the Ethics Committee of the National School of Sport University Institution, under memorandum number 40.07.247. In accordance with Resolution 008430 of 1993 from the Ministry of Health, this research poses no risk, as it employs retrospective documentary research techniques and methods, and no intervention or intentional modification of biological, physiological, psychological, or social variables is conducted. The information obtained will be strictly confidential, as stipulated in Articles 1 and 14 of Resolution 1995 of July 8, 1999, from the Ministry of Health of Colombia. All data obtained will be used solely for research purposes and collected in standardized formats.

Conflict of Interest Statement

Financial entities or institutions had no influence on the study design, data analysis, or interpretation of the results.

Funding

Funding was received from the National School of Sport University Institution.

Authors' Contribution

Olga Lucía Hincapié Gallón: Conceptualization, Formal Analysis, Fundraising, Research, Methodology, Project Management, Resources, Supervision, Validation, Visualization, Drafting, Revision, and Editing.

Lina Marcela Tierradentro Gómez: Methodology, Validation, Visualization, Drafting, Revision, and Editing.

Julián Andrés Rivera Motta: Conceptualization, Data Curation, Formal Analysis, Draft, Research.

All authors have read and agree with the published version of the manuscript.

Data Availability Statement

Data are unavailable due to ethical restrictions.

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