# Physiological profile of elite female road cyclists from Antioquia, Colombia: a cross-sectional study

*Perfil fisiológico de ciclistas de ruta elite femeninas de Antioquia, Colombia: un estudio transversal*

## Authors

Santiago Cano-Giraldo [1,2]
Juan D. Ascuntar-Viteri [2,3]
Juan D. Quintero [2,3]
Andrés F. Rodríguez-Hernández [2]
Andrés M. Cadavid [2]
Sergio López-Betancourt [2]
Natalia Acosta-Arroyave [4]
Andrés Rojas Jaramillo [1,2,3]

[1] Universidad de Antioquia, Medellín, Colombia
[2] Corporación Universitaria Minuto de Dios, Medellín, Colombia
[3] Dynamical Business & Science Society—DBSS International SAS, Bogotá, Colombia
[4] Universidad Pontificia Bolivariana, Medellín, Colombia

Corresponding author:
Andrés Rojas Jaramillo
andres.rojasj@udea.edu.co

Received: 11-06-25
Accepted: 11-08-25

## How to cite in APA

Cano-Giraldo, S., Ascuntar-Viteri, J. D., Quintero, J. D., Rodríguez-Hernández, A. F., Cadavid, A. M., López-Betancourt, S., Acosta-Arroyave, N., & Rojas-Jaramillo, A. (2025). Physiological profile of elite female road cyclists from Antioquia, Colombia: a cross-sectional study. *Retos, 72*, 589-597. https://doi.org/10.47197/retos.v72.116571

## Abstract

Background: This study aimed to describe the physiological profile of elite female cyclists from the department of Antioquia, Colombia. A quantitative, descriptive, and cross-sectional design was used, with data collected at a single time point.
Methods: The sample included 13 professional female cyclists from the team "Mujeres Antioquia – Orgullo Paisa." Assessments included resting metabolic rate test, countermovement jump (CMJ), and a cycle ergometer cardiopulmonary exercise test.
Results: Resting substrate utilization revealed a carbohydrate consumption of 49.1 (39.6) % and fat consumption of 50.9 (39.6) %. The CMJ height was 25.9 (3.87) cm with a reactive strength index (RSI) of 0.510 (0.0936). During cycle ergospirometry, the oxygen consumption at ventilatory threshold 1 (VT1) was 36.1 (4.39) $ml \cdot kg^{-1} \cdot min^{-1}$, with a corresponding power output of 144 (30.9) W and an efficiency of 68.7 (5.01) %. At VT2, oxygen consumption reached 47.6 (6.33) $ml \cdot kg^{-1} \cdot min^{-1}$, with a power output of 215 (26.5) W and an efficiency of 90.4 (4.83) %. The maximal oxygen uptake ($VO_2max$) was 52.6 (4.9) $ml \cdot kg^{-1} \cdot min^{-1}$, and the power output was 287 (22.8) W.
Discussion: The values for $VO_2max$ (52.6 ± 4.9) and peak power output (287 ± 22.8 W) were moderate compared to international standards. Despite this, the cyclists from Antioquia showed a higher percentage of $VO_2max$ utilization at VT2 (90.4 ± 4.8%), indicating a high physiological efficiency for prolonged efforts, which is crucial in road cycling.
Conclusion: These findings provide a physiological reference point for performance monitoring and training planning in Colombian women's cycling.

## Keywords

Female cyclists; neuromuscular performance; physiological profile; ventilatory thresholds; $VO_2max$.

## Resumen

Antecedentes: Este estudio tuvo como objetivo describir el perfil fisiológico de ciclistas de élite del departamento de Antioquia, Colombia. Se empleó un diseño cuantitativo, descriptivo y transversal, con datos recolectados en un único momento.
Métodos: La muestra incluyó a 13 ciclistas profesionales del equipo "Mujeres Antioquia – Orgullo Paisa". Las evaluaciones incluyeron la prueba de tasa metabólica en reposo, el salto con contramovimiento (CMJ) y una prueba de ejercicio cardiopulmonar en cicloergómetro.
Resultados: La utilización de sustratos en reposo reveló un consumo de carbohidratos del 49,1 (39,6) % y un consumo de grasas del 50,9 (39,6) %. La altura del CMJ fue de 25,9 (3,87) cm con un índice de fuerza reactiva (RSI) de 0,510 (0,0936). Durante la cicloergoespirometría, el consumo de oxígeno en el umbral ventilatorio 1 (VT1) fue de 36,1 (4,39) $ml \cdot kg^{-1} \cdot min^{-1}$, con una potencia de salida correspondiente de 144 (30,9) W y una eficiencia del 68,7 (5,01) %. En VT2, el consumo de oxígeno alcanzó 47,6 (6,33) $ml \cdot kg^{-1} \cdot min^{-1}$, con una potencia de salida de 215 (26,5) W y una eficiencia del 90,4 (4,83) %. El consumo máximo de oxígeno ($VO_2máx$) fue de 52,6 (4,9) $ml \cdot kg^{-1} \cdot min^{-1}$, y la potencia de salida fue de 287 (22,8) W.
Discusión: Los valores de $VO_2max$ (52.6 ± 4.9) y potencia pico (287 ± 22.8 W) fueron moderados en comparación con referencias internacionales. A pesar de esto, las ciclistas de Antioquia mostraron un mayor porcentaje de utilización del $VO_2max$ en el VT2 (90.4 ± 4.8%), indicando una alta eficiencia fisiológica para esfuerzos prolongados, algo crucial en el ciclismo de ruta.
Conclusión: Estos hallazgos proporcionan un punto de referencia fisiológico para la monitorización del rendimiento y la planificación del entrenamiento en el ciclismo femenino colombiano.

## Palabras clave

Ciclistas femeninas; perfil fisiológico; rendimiento neuromuscular; umbrales ventilatorios; $VO_2máx$.

## Introduction

Women's road cycling has gained significant prominence in recent years as an emerging discipline with high physiological demands(Van Reeth, 2022). However, it still receives less scientific attention compared to male cycling, highlighting the urgent need to better understand the physiological requirements and performance characteristics of professional female (Abbiss et al., 2010; Mateo-March et al., 2022; Menaspà et al., 2017; Peiffer et al., 2018; Sanders et al., 2019; van Erp & Lamberts, 2023). Compared to male cycling, the scientific literature focused on women remains limited (Herrero-Molleda et al., 2023; Sanders et al., 2019; Van Reeth, 2022).

One of the main features of women's road cycling is the prolonged duration of competitions, both in time and distance. Female cyclists must also perform short, high-intensity sprints. In high-level competitions such as the Grand Tours, athletes typically cover distances ranging from 120 to 150 kilometers per stage, with durations of 4 to 6 hours depending on the route profile (VAN Erp, 2021). However, competition formats vary and may include single-day events such as criteriums, time trials, point-to-point races, and multi-lap road race, as well as stage races lasting up to three weeks. In other races, such as the classics, stages can last from 4 to 7.5 hours, making this sport highly demanding both physically and mentally.

These prolonged efforts also include moments of very high intensity. It has been observed, for example, that the top 10 finishers in World Cup events perform more short efforts—exceeding 20 sprints per stage on flat terrain, 40 in mountain stages, and 60 in criteriums (Herrero-Molleda et al., 2023) . These demands require training load monitoring based on objective criteria, especially considering that although female professional cyclists typically train at lower volumes than male cyclists, they compensate with higher-intensity sessions (VAN Erp, 2021). This underscores the need for individualized training programs that take into account physiological gender differences and the variation in performance parameters between elite and professional cyclists.

In addition, the physiological demands of road cycling differ between sexes, particularly in terms of training load and volume. While male cyclists tend to spend more time in high-intensity zones, female cyclists often train at relatively higher intensities (Herrero-Molleda et al., 2023; Sanders & Heijboer, 2019). The most noticeable differences are found in submaximal parameters, such as relative and absolute power at $VO_2$max, and at the aerobic (VT1) and anaerobic (VT2) thresholds, where female cyclists sometimes demonstrate greater efficiency (Lucía et al., 1998; Martin et al., 2001). For instance, $VO_2$max values among female cyclists range from 57 to 63.6 $mL \cdot kg^{-1} \cdot min^{-1}$, while peak lower-limb power output varies between 192 W and 322 W (Ebert et al., 2005; Garvican et al., 2011); similarly, absolute power at $VO_2$max is around 333 W, with 83.6% of $VO_2$max being utilized at VT2 (Martin et al., 2001). Other studies have shown correlations between neuromuscular and anaerobic indicators—such as peak power in the Wingate test and performance in the countermovement jump (CMJ) (Muriel Otegui et al., 2012), demonstrating the link between mechanical efficiency and athletic performance.

Despite the growing presence of women in international cycling competitions, global participation remains limited. For example, in the 2020 Women's WorldTour, there were only 106 female cyclists (versus 544 men), 8 teams (versus 19), and 23 races (versus 38). Furthermore, 75% of the participants were European, and only 7% were from the Americas. This limited representation reinforces the need to generate context-specific scientific evidence in regions such as Latin America, where women's cycling is still in the process of consolidation (Van Reeth, 2022).

In this context, the aim of this cross-sectional study is to explore the physiological demands of Colombian female road cyclists through the analysis of neuromuscular and metabolic parameters, including resting, submaximal, and maximal indicators. This study was designed and reported in accordance with the STROCSS 2024 guidelines for cross-sectional studies (Rashid et al., 2024).

## Method

This study employed a quantitative, descriptive, and cross-sectional design with a partially inferential approach. Data were collected prospectively at a single time point, aiming to characterize the physiological demands of high-performance female road cyclists. The assessments were conducted on August 15, 2022, at the Physiology Laboratory of Indeportes Antioquia, located in Medellín, Colombia.

This institution operates as a public center dedicated to supporting high-performance sports. All evaluations were carried out under controlled conditions between 6:00 a.m. and 11:00 a.m. Participants were previously contacted and scheduled to attend on that specific date and time in order to follow the established testing protocol. A non-probabilistic sampling method was used, and the sample was selected at the researcher's convenience, based on participant availability.

## *Participants*

The final sample consisted of 13 female athletes, aged between 14 and 23 years, all of whom were high-level.

### *Eligibility criteria*

Participants were eligible for inclusion if they met the following criteria: being a member of the "Mujeres Antioquia – Orgullo Paisa" cycling team, providing signed informed consent (and informed assent when applicable), being between 14 and 23 years of age, and having no medical conditions that would limit participation in sports activities.
Exclusion criteria included: the presence of any health condition that restricted physical activity; failure to complete the full evaluation session; use of psychoactive substances, alcohol, or performance-enhancing drugs; sustaining an injury during the study period; or failure to provide informed consent or assent

## *Procedure*

Upon arrival at the laboratory, participants received detailed information about the study and signed the corresponding informed consent (and assent when applicable). Subsequently, the evaluation protocol was initiated, which included the following steps:

1. Assessment of fasting basal metabolism (minimum 12 hours of fasting).
2. Maximal incremental test on a cycling simulator (Cyclus 2), with breath-by-breath respiratory analysis using the COSMED QUARK RMR metabolic device.
3. Neuromuscular assessment via countermovement jump (CMJ), using the Vald ForceDecks Dual Force Plate System.

The day after the resting metabolic rate test, the warm-up was standardized and consisted of 8 minutes of moderate-intensity cycling and 5 CMJ, followed by a 3 minute rest before beginning the tests. The CMJ test was performed first, where each cyclist completed five jumps. The highest and lowest jump were discarded, and the mean of the remaining three was used for analysis, with a 50 second rest interval between each attempt. Subsequently, the load–velocity curve and the incremental cardiopulmonary exercise test (CPET) were performed. The CPET was conducted on a cycle ergometer using the COSMED Quark RMR system. The incremental protocol began at 75 watts and increased by 30 watts every two minutes. The test was terminated upon volitional exhaustion, defined as the inability to maintain a pedaling cadence. The day after the resting metabolic rate test, the warm up was standardized and consisted of 8 minutes of moder and 75 revolutions per minute.

### *Instrument*

Measurements were obtained using the following instruments: oxygen consumption and metabolism were assessed with the COSMED QUARK RMR analyzer; pedaling power was measured using the Cyclus 2 cycle ergometer; CMJ and FT:CT were recorded with the Vald ForceDecks Dual Force Plate System. Body weight was measured using a Sport Fitness scale following a 12-hour overnight fast; height was assessed with a standardized stadiometer, and age was verified through official identification.

## *Variables Assessed*

The evaluation included physiological, neuromuscular, anthropometric, and demographic measurements. Physiological variables comprised maximal oxygen uptake ($VO_2max$, $mL \cdot kg^{-1} \cdot min^{-1}$), peak power output at $VO_2max$ (W), aerobic (VT1) and anaerobic thresholds (VT2), power output at VT1 and VT2 (W), and the percentage of $VO_2max$ utilization at each threshold.
Neuromuscular performance was evaluated through countermovement jump (CMJ) height (cm) and the flight time to contraction time ratio (FT:CT).

Anthropometric and demographic variables included body weight (kg), height (cm), and age (years).

### *Data analysis*

Data normality was assessed using the Shapiro–Wilk test. Since the data followed a normal distribution, univariate analyses were performed using mean and standard deviations. For bivariate analysis, Pearson's correlation coefficient was applied, with a significance level set at $p < 0.05$ and 95% confidence intervals. All statistical analyses were conducted using Jamovi, R, and IBM SPSS software

### *Ethical Considerations*

The study complied with the Declaration of Helsinki and Resolution 8430 of 1993 issued by the Colombian Ministry of Health and was classified as minimal risk. Ethical approval was granted by the Ethics Committee of the Instituto Universitario de Educación Física y Deporte at the Universidad de Antioquia. All participants—and/or their legal guardians—signed informed consent and assent, as applicable. For participants under 18 years of age (range: 14–18), ethical considerations were carefully addressed. Informed assent was obtained from the athletes, along with signed consent forms from their legal guardians. These procedures ensured full compliance with national and international ethical standards for research involving minors.

## Results

Table 1 presents the descriptive statistics for height and body weight of the participants.

Table 1. Descriptive statistics for height and body weight

| Variables | N | Mean | Standard deviation |
|---|---|---|---|
| Height (cm) | 13 | 162 | 5.31 |
| Weight (kg) | 13 | 55.9 | 4.65 |

Abbreviations: N: Number, CM: centimeters, KG: Kilograms

The mean height was 162.0 cm with a standard deviation of 5.31 cm. On the other hand, the mean body weight was 55.9 kg with a standard deviation of 4.65 kg.

Table 2 summarizes the descriptive statistics for the physiological and neuromuscular performance variables obtained during the testing protocol, including resting substrate utilization, ventilatory thresholds, $VO_2$max, and countermovement jump performance.

Table 2. Descriptive statistics for performance variables.

| Variable | Mean (SD) [95% CI] |
|---|---|
| Resting CHO Consumption (%) | 49.1 (39.6) [22.5-75.7] |
| Resting Fat Consumption (%) | 50.9 (39.6) [24.3-77.5] |
| $VO_2$ at VT1 (ml·kg$^{-1}$·min$^{-1}$) | 36.1 (4.39) [33.5-38.8] |
| Power at VT1 (W) | 144 (30.9) [126-163] |
| % $VO_2$ Utilization at VT1 | 68.7 (5.01) [65.7-71.8] |
| $VO_2$ at VT2 (ml·kg$^{-1}$·min$^{-1}$) | 47.6 (6.33) [43.8-51.5] |
| Power at VT2 (W) | 215(26.5) [199-231] |
| % $VO_2$ Utilization at VT2 | 90.4 (4.83) [87.4-93.3] |
| $VO_2$max (ml·kg$^{-1}$·min$^{-1}$) | 52.6(4.9) [49.6-55.5] |
| Power at $VO_2$max (W) | 287 (22.8) [274-301] |
| CMJ Height (cm) | 25.9 (3.87) [23.6-28.3] |
| Modified RSI | 0.510 (0.0936) [0.453-0.567] |

Abbreviations: SD: Standard Deviation, CI: confidence interval, CHO: Carbohydrates, RSI: Reactive Strength Index, VO2: Oxygen uptake, VO2max: Maximal oxygen uptake, VT1: Aerobic threshold, VT2: Anaerobic threshold, W: Watts

Among the maximal performance values obtained during the incremental Conconi protocol, the mean $VO_2$max was 52.6 (4.9) mL·kg$^{-1}$·min$^{-1}$, with a corresponding peak power output of 287 (22.8) watts. In addition, the mean percentage of $VO_2$max utilization at VT2 was 90.4% (4.83), with an absolute power output of 215 (26.5) watts. Similarly, the percentage of $VO_2$max utilization at VT1 averaged 68.7% (5.01), with a power output of 144 (30.9) watts.

These results highlight the efficiency of each ventilatory threshold in terms of both $VO_2$ utilization and power generation, suggesting that meaningful performance differences may exist between VT1 and VT2.

*Bivariate analysis*

Table 3 shows the Pearson correlation coefficients and 95% confidence intervals between selected performance variables, including $VO_2$max power, ventilatory threshold power outputs, CMJ height, and the modified RSI

Table 3. Pearson correlations between performance variables.

| | | Power at $VO_2$Max | Power at VT1 | Power at VT2 | CMJ height | Modified RSI |
|---|---|---|---|---|---|---|
| | Pearson correlation | — | | | | |
| Power at $VO_2$max | Upper 95% CI | — | | | | |
| | Lower 95% CI | — | | | | |
| | Pearson correlation | 0.499 | — | | | |
| Power at VT1 | Upper 95% CI | 0.824 | — | | | |
| | Lower 95% CI | -0.072 | — | | | |
| | Pearson correlation | 0.498 | 0.061 | — | | |
| Power at VT2 | Upper 95% CI | 0.823 | 0.592 | — | | |
| | Lower 95% CI | -0.074 | -0.507 | — | | |
| | Pearson correlation | -0.151 | -0.414 | 0.474 | — | |
| CMJ height | Upper 95% CI | 0.436 | 0.177 | 0.813 | — | |
| | Lower 95% CI | -0.648 | -0.788 | -0.104 | — | |
| | Pearson correlation | -0.164 | -0.250 | 0.030 | 0.871 | — |
| Modified RSI | Upper 95% CI | 0.425 | 0.349 | 0.572 | 0.098 | — |
| | Lower 95% CI | -0.656 | -0.704 | -0.530 | 0.096 | — |

Note: p < .05, ** p < .01, *** p < .001

Power at $VO_2$max showed a moderate positive correlation with power at VT1 and also with power at VT2. However, it presented a weak negative correlation with CMJ height and the modified RSI. None of these correlations were statistically significant.

Moreover, power at VT1 had no correlation with power at VT2. Nonetheless, it showed a moderate negative correlation with CMJ height and a weak negative correlation with the modified RSI, although none of these relationships reached statistical significance. In addition, power at VT2 demonstrated a moderate correlation with CMJ height, but no correlation with the modified RSI. These associations were also not statistically significant.

Finally, CMJ height was strongly correlated with the modified RSI, but this relationship was not statistically significant.

## Discussion

This study allowed the establishment of a physiological profile for professional female cyclists from the department of Antioquia, Colombia. This profile may contribute to talent identification strategies and the design of more specific training programs for women. The variables evaluated showed weak to moderate correlations, without reaching a sufficient level of certainty to confirm clear associations among them. These findings suggest the potential existence of relevant physiological associations that may require larger sample sizes to be confirmed. Nonetheless, the results obtained offer a valuable baseline for talent identification and training planning in Colombian women's cycling.

Regarding maximal values, the average $VO_2$max was 52.6 ± 4.9 $mL\cdot kg^{-1}\cdot min^{-1}$, and the peak power output reached 287 ± 22.8 W. These values indicate a moderate level of cardiorespiratory performance when compared to international references. For instance, (Martin et al., 2001) reported $VO_2$max values between 57.4 and 64.2 $mL\cdot kg^{-1}\cdot min^{-1}$ and peak power outputs up to 331 W in female cyclists from the United States national team. Although these figures are not directly comparable due to differences in geographic, cultural, and competitive contexts, they help to contextualize the current level of performance among the cyclists assessed in this study. It is important to note that the assessments were conducted in Medellín, located at approximately 1,500 meters above sea level (Caballero et al., 2008). From this altitude, $VO_2$max decreases linearly with increasing elevation, even from 800 meters, with an average reduction of 6.3% per 1,000 meters, even in trained athletes (Wehrlin & Hallén, 2006). Although the cyclists evaluated in this study are chronically acclimatized to this altitude, some research indicates that $VO_2$max may still be moderately reduced at elevations starting from 2,000 meters, even in acclimatized individuals, particularly those with high cardiovascular capacity (Pühringer et al., 2022). Therefore, it is plausible that altitude partially influenced the values obtained, and this should be considered when comparing the results with populations assessed at sea level.

When comparing the results of the present study with previous research on high-level female cyclists, similarities and differences are evident in both the methodologies employed and the values obtained. Regarding $VO_2$max, the average value observed in this study (59.3 ± 3.2 ml·kg$^{-1}$·min$^{-1}$) was higher than those reported by (Støa et al., 2024)(56.7 ± 4.8), (Jurov et al., 2023)(57.8 ± 3.5), and (Alejo et al., 2022) (55.9 ± 2.7). This difference could be explained by the use of direct protocols with gas analysis, as well as participant-specific characteristics such as competitive level or the phase of the training cycle. Although these differences are not accompanied by effect sizes in all cases, the trend suggests a greater development of cardiovascular capacity in the evaluated sample. Regarding relative power output, the values found (4.5 W/kg) also slightly exceeded those reported by (Jurov et al., 2023)(4.1 W/kg) and (Alejo et al., 2022)(4.2 W/kg), which is consistent with the $VO_2$max data. It is worth noting that, unlike the aforementioned studies, the present protocol included submaximal variables such as ventilatory thresholds, neuromuscular parameters such as CMJ and the RSI, allowing for a more comprehensive characterization of the athletes' physiological profile. These methodological differences may influence the interpretation of results and highlight the need to consider multiple functional dimensions in performance analysis.

Beyond maximal indicators, the submaximal variables yielded particularly interesting results. The percentage of $VO_2$max utilization at VT2 was 90.4 ± 4.8%, which is higher than the 83.6% reported by (Martin et al., 2001). This may reflect a high level of physiological efficiency in sustaining prolonged efforts—a critical quality in disciplines such as time trials and mountain stages. This type of efficiency has been linked not only to central adaptations, such as increased cardiac output, but also to peripheral adaptations at the muscular level. In a recent study by (Inglis et al., 2025), it was found that after six weeks of intensity-specific training, changes in $VO_2$max among trained athletes were more strongly related to peripheral adaptations—such as enhanced muscular oxygen utilization—than to central cardiovascular changes. This finding is consistent with the potential efficiency observed in the athletes evaluated in this study. However, the absolute power output at VT2 was 215 ± 26.5 W, indicating potential for improvement in sustained submaximal performance.

This pattern of results becomes even more relevant when considering existing literature. (Sanders & Heijboer, 2019) found that professional cyclists spend more than 65% of the time below VT1 during Grand Tours. This reinforces the importance of optimizing submaximal intensity performance, an area that, based on the present study, may represent a strength in this population. Similarly, (Hue et al., 2000) observed VT2 values around 74% of $VO_2$max in female triathletes, emphasizing its importance as a performance marker. The fact that the Antioquia cyclists presented a higher value may indicate a physiological adaptation specific to their training environment or competitive model.

A major strength of this study is its specific focus on a poorly documented population in the literature, professional female cyclists in Colombia. The application of standardized physiological tests under controlled conditions provides rigorous data that can serve as a foundation for future research and training strategy planning. In addition, the study included key performance variables in cycling, such as $VO_2$max, peak power output, and ventilatory thresholds.

One of the limitations of this study is the small sample size, which is understandable given the exclusive nature of the target population. This may have limited the identification of statistically significant associations between variables. Additionally, the cross-sectional design did not allow for the observation of longitudinal changes in physiological profiles. Although indirect comparisons were made with international data, it was not possible to include a control or comparison group to more precisely contextualize the performance level of the evaluated cyclists in relation to other teams or competitive categories. Furthermore, the protocol did not include complementary variables such as body composition, nutritional status, or hormonal indicators, despite their potential relevance to cardiorespiratory, metabolic, and neuromuscular performance in female athletes. While these exclusions were due to logistical and methodological considerations, their inclusion in future research could contribute to a more comprehensive understanding of the determinants of performance in women's cycling.

This study represents an important contribution to the physiological characterization of professional female cyclists in Colombia. By providing objective data on key performance variables, this study contributes to the development of a necessary scientific foundation to strengthen the preparation of female athletes at the national level. The findings are relevant not only in academic settings but also in applied contexts such as training design, performance evaluation, and selection processes within professional teams. Notably, the high percentage of $VO_2$max utilization at VT2 suggests that these athletes could benefit from specific strategies aimed at maintaining and enhancing this capacity, while also focusing on improving absolute power output.

Future research should aim to expand the sample to include teams from different regions and levels of professionalization. Longitudinal designs would allow the monitoring of physiological adaptations over time, offering a deeper understanding of athlete development. Additionally, integrating complementary variables such as body composition, pedaling efficiency, recovery markers, and psychosocial factors could enrich the multidimensional analysis of performance. As women's cycling continues to gain structure and visibility in Colombia, establishing population-specific physiological benchmarks supported by scientific data is essential to promote the sustainable and strategic growth of the sport. This study lays the foundation for future advancements in applied sport science, offering tools to inform technical, medical, and institutional decision-making.

## Conclusions

This study presents one of the first physiological profiles of elite female road cyclists in Colombia. The results highlight a moderate $VO_2$max and high submaximal efficiency, suggesting a well-developed capacity to sustain prolonged efforts despite limited peak power. These findings provide relevant benchmarks for athlete monitoring and training design and underline the need for longitudinal and multicenter studies to better understand female cycling performance in Latin America.

## Highlights

1. First study profiling elite female cyclists from Antioquia, Colombia.
2. High submaximal $VO_2$ utilization at VT2 despite moderate $VO_2$max.
3. Neuromuscular variables showed no clear correlation with power output.
4. Findings serve as the baseline for future training and selection strategies.
5. Suggestions are needed for region-specific benchmarks in women's cycling.

## Financing

No funding.

## References

Abbiss, C. R., Straker, L., Quod, M. J., Martin, D. T., & Laursen, P. B. (2010). Examining pacing profiles in elite female road cyclists using exposure variation analysis. *Br J Sports Med*, *44*(6), 437-442. https://doi.org/10.1136/bjsm.2008.047787

Alejo, L. B., Montalvo-Pérez, A., Valenzuela, P. L., Revuelta, C., Ozcoidi, L. M., de la Calle, V.,...Barranco-Gil, D. (2022). Comparative analysis of endurance, strength and body composition indicators in professional, under-23 and junior cyclists. *Front Physiol*, *13*, 945552. https://doi.org/10.3389/fphys.2022.945552

Caballero, A., Torres-Duque, C. A., Jaramillo, C., Bolívar, F., Sanabria, F., Osorio, P.,…Maldonado, D. (2008). Prevalence of COPD in five Colombian cities situated at low, medium, and high altitude (PREPOCOL study). *Chest*, *133*(2), 343-349. https://doi.org/10.1378/chest.07-1361

Ebert, T. R., Martin, D. T., McDonald, W., Victor, J., Plummer, J., & Withers, R. T. (2005). Power output during women's World Cup road cycle racing. *Eur J Appl Physiol*, *95*(5-6), 529-536. https://doi.org/10.1007/s00421-005-0039-y

Garvican, L. A., Pottgiesser, T., Martin, D. T., Schumacher, Y. O., Barras, M., & Gore, C. J. (2011). The contribution of haemoglobin mass to increases in cycling performance induced by simulated LHTL. *Eur J Appl Physiol*, *111*(6), 1089-1101. https://doi.org/10.1007/s00421-010-1732-z

Herrero-Molleda, A., Álvarez-Álvarez, M. J., Floría, P., & García-López, J. (2023). Training Characteristics and Competitive Demands in Women Road Cyclists: A Systematic Review. *Int J Sports Physiol Perform*, *18*(8), 794-804. https://doi.org/10.1123/ijspp.2023-0038

Hue, O., Le Gallais, D., Chollet, D., & Préfaut, C. (2000). Ventilatory threshold and maximal oxygen uptake in present triathletes. *Can J Appl Physiol*, *25*(2), 102-113. https://doi.org/10.1139/h00-007

Inglis, E. C., Rasica, L., Iannetta, D., Sales, K. M., Keir, D. A., MacInnis, M. J., & Murias, J. M. (2025). Exercise training-induced speeding of $${\dot{\text{V}}\text{O}}_{{2}}$$kinetics is not intensity domain-specific or correlated with indices of exercise performance. *Eur J Appl Physiol*, *125*(5), 1297-1310. https://doi.org/10.1007/s00421-024-05674-1

Jurov, I., Toplišek, J., & Cvijić, M. (2023). Prediction of Maximal Oxygen Consumption in Cycle Ergometry in Competitive Cyclists. *Life (Basel)*, *13*(1). https://doi.org/10.3390/life13010160

Lucía, A., Pardo, J., Durántez, A., Hoyos, J., & Chicharro, J. L. (1998). Physiological differences between professional and elite road cyclists. *Int J Sports Med*, *19*(5), 342-348. https://doi.org/10.1055/s-2007-971928

Martin, D. T., McLean, B., Trewin, C., Lee, H., Victor, J., & Hahn, A. G. (2001). Physiological characteristics of nationally competitive female road cyclists and demands of competition. *Sports Med*, *31*(7), 469-477. https://doi.org/10.2165/00007256-200131070-00002

Mateo-March, M., van Erp, T., Muriel, X., Valenzuela, P. L., Zabala, M., Lamberts, R. P.,…Pallarés, J. G. (2022). The Record Power Profile in Professional Female Cyclists: Normative Values Obtained From a Large Database. *Int J Sports Physiol Perform*, *17*(5), 682-686. https://doi.org/10.1123/ijspp.2021-0372

Menaspà, P., Sias, M., Bates, G., & La Torre, A. (2017). Demands of World Cup Competitions in Elite Women's Road Cycling. *Int J Sports Physiol Perform*, *12*(10), 1293-1296. https://doi.org/10.1123/ijspp.2016-0588

Muriel Otegui, X., Cámara Tobalina, J., Fernández López, J. R., & Pallarés, J. G. (2012). Validity of the jump test for assessing the anaerobic perfomance and asymmetry in elite cyclists. *SPORT TK-EuroAmerican Journal of Sport Sciences*, *1*(1), 39-45. https://doi.org/10.6018/185541

Peiffer, J. J., Abbiss, C. R., Haakonssen, E. C., & Menaspà, P. (2018). Sprinting for the Win: Distribution of Power Output in Women's Professional Cycling. *Int J Sports Physiol Perform*, *13*(9), 1237-1242. https://doi.org/10.1123/ijspp.2017-0757

Pühringer, R., Gatterer, H., Berger, M., Said, M., Faulhaber, M., & Burtscher, M. (2022). Does Moderate Altitude Affect VO(2)max in Acclimatized Mountain Guides? *High Alt Med Biol*, *23*(1), 37-42. https://doi.org/10.1089/ham.2021.0081

Rashid, R., Sohrabi, C., Kerwan, A., Franchi, T., Mathew, G., Nicola, M., & Agha, R. A. (2024). The STROCSS 2024 guideline: strengthening the reporting of cohort, cross-sectional, and case-control studies in surgery. *Int J Surg*, *110*(6), 3151-3165. https://doi.org/10.1097/js9.0000000000001268

Sanders, D., & Heijboer, M. (2019). Physical demands and power profile of different stage types within a cycling grand tour. *Eur J Sport Sci*, *19*(6), 736-744. https://doi.org/10.1080/17461391.2018.1554706

Sanders, D., van Erp, T., & de Koning, J. J. (2019). Intensity and Load Characteristics of Professional Road Cycling: Differences Between Men's and Women's Races. *Int J Sports Physiol Perform*, *14*(3), 296-302. https://doi.org/10.1123/ijspp.2018-0190

Støa, E. M., Rønnestad, B., Helgerud, J., Johansen, J. M., Andersen, I. T., Rogneflåten, T.,…Støren, Ø. (2024). Short-time cycling performance in young elite cyclists: related to maximal aerobic power and not to maximal accumulated oxygen deficit. *Front Physiol*, *15*, 1536874. https://doi.org/10.3389/fphys.2024.1536874 van Erp, T., & Lamberts, R. P. (2023). Demands of professional female cycling races: Influence race level and race duration (single or multi-day events). *Eur J Sport Sci*, *23*(8), 1463-1471. https://doi.org/10.1080/17461391.2022.2111277

VAN Erp, T., Sanders, D., & Lamberts, R. P. (2021). Maintaining Power Output with Accumulating Levels of Work Done Is a Key Determinant for Success in Professional Cycling. *Med Sci Sports Exerc*, *53*(9), 1903-1910. https://doi.org/10.1249/mss.0000000000002656

Van Reeth, D. (2022). Globalization in Professional Road Cycling. In D. Van Reeth (Ed.), *The Economics of Professional Road Cycling* (pp. 337-367). Springer International Publishing. https://doi.org/10.1007/978-3-031-11258-4_14

Wehrlin, J. P., & Hallén, J. (2006). Linear decrease in .VO2max and performance with increasing altitude in endurance athletes. *Eur J Appl Physiol*, *96*(4), 404-412. https://doi.org/10.1007/s00421-005-0081-9

## Authors' and translators' details:


| | | |
|---|---|---|
| Santiago Cano-Giraldo | Santiago.canog@udea.edu.co | Author |
| Juan D. Ascuntar-Viteri | juandavid17121997@gmail.com | Author |
| Juan D. Quintero | Juanquintero.jdqm@electronico.com | Author |
| Andrés F. Rodríguez-Hernández | andres.rodriguez04@uptc.edu.co | Author |
| Andrés M. Cadavid | andres_cadavid80221@elpoli.edu.co | Author |
| Sergio López-Betancourt | sergio.lopezbetancourt@uptc.edu.co | Author |
| Natalia Acosta-Arroyave | natalia.acosta.ar@gmail.com | Author |
| Andrés Rojas Jaramillo | arojasj@unal.edu.co | Author |
| Full name | natalia.acosta.ar@gmail.com | Translator |