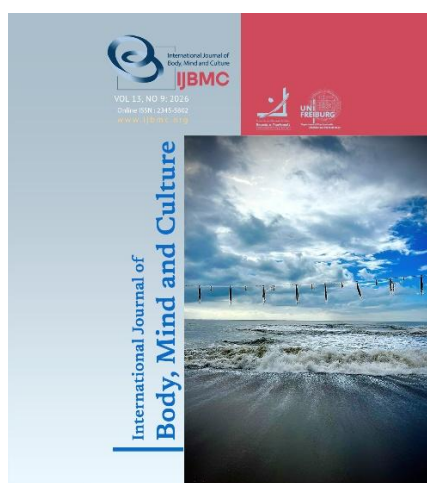


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Wearable-Derived Physiological and Pacing Responses in a Recreational 10K Race: A Descriptive Case Study of Two Recreational Runners

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ABSTRACT

Objective: This study aimed to descriptively compare pacing patterns and wearable-derived physiological indicators during a recreational 10K race.

Methods and Materials: A descriptive case-study design was used involving two recreational runners who participated in the same 10 km road race. Running pace, heart rate, estimated energy expenditure, and smartwatch-derived VO₂Max estimates were recorded using the same wearable device model. Kilometer-by-kilometer pacing and overall race metrics were compared descriptively.

Findings: Both participants completed the race with relatively similar pacing trends, including a pacing decline during the middle segments of the race followed by a slight increase in pace toward the final kilometers. Despite differences in estimated VO₂Max and total energy expenditure, the finishing time difference between participants was relatively small (54 seconds). Heart rate responses indicated different physiological demands between the two runners across the race.

Conclusion: These observations illustrate how wearable-derived metrics may reveal individual differences in pacing and physiological responses even within a similar race context. However, due to the extremely small sample size and the use of consumer wearable estimates, the findings should be interpreted as exploratory and descriptive rather than generalizable.

Keywords: Recreational Running, Wearable Technology, Pacing, Heart Rate, VO₂Max.

Introduction

Running is one of the most widely practiced forms of physical activity worldwide due to its accessibility and well-documented health benefits (Braschler et al., 2024). Recreational road races such as 5 km and 10 km events have become increasingly popular among individuals with diverse fitness backgrounds, providing opportunities for participants to monitor performance and improve physical fitness (Yang et al., 2022).

In recent years, wearable technologies such as smartwatches and fitness trackers have become common tools for recreational runners to monitor training and competition performance (Clermont et al., 2020; Wang, 2015). These devices provide real-time estimates of performance-related and physiological indicators, including running pace, heart rate, energy expenditure, and estimated maximal oxygen uptake (VO_2Max). Although these measurements are derived from consumer algorithms rather than laboratory assessments, wearable devices offer practical insights into physiological responses during real-world running activities (Braschler et al., 2024).

Pacing strategy is considered an important factor influencing endurance running performance (Carbillet, 2019; Skorski & Abbiss, 2017). Previous studies have demonstrated that pacing patterns may vary depending on physiological capacity, aerobic fitness, and race conditions (Chalabaev et al., 2017). Aerobic capacity, commonly represented by VO_2Max , is often associated with endurance performance and the ability to sustain effort during prolonged running activities (Hernández-Flórez et al., 2025). However, recreational runners frequently display considerable variability in pacing behavior and physiological responses even when competing under similar environmental conditions.

Although many studies have investigated pacing strategies and physiological determinants of endurance performance in elite athletes or large

sample populations, fewer studies have descriptively examined wearable-derived performance and physiological indicators in real-world race environments among recreational runners (Dai et al., 2025; Domingo et al., 2020). Observational comparisons between individual runners may provide useful insights into how pacing patterns and physiological responses emerge during recreational competitions.

Therefore, the purpose of this study was to descriptively compare pacing patterns and wearable-derived physiological indicators between two recreational runners participating in the same 10 km road race. The study specifically examined the relationship between external race performance and internal physiological load in two individuals with different estimated aerobic capacities competing under similar environmental conditions.

Materials and Methods

Research Design

This study used a descriptive case study design to compare pacing patterns and wearable-derived physiological responses of two recreational runners participating in the same 10 km road race. The study was observational in nature and did not involve any experimental manipulation. Instead, it examined naturally occurring race data obtained during participation in the Bukittinggi Police Run 10K.

The objective of the study was to descriptively compare external performance outcomes (race duration and pacing) and internal physiological indicators (heart rate responses, estimated energy expenditure, and smartwatch-derived VO_2Max estimates) between two runners competing under the same race conditions. Because both participants ran the same course at the same event, environmental factors such as course profile, elevation, and weather conditions were assumed to be similar for both individuals. Given the extremely small sample size, the purpose of this design was not

to generate generalizable conclusions, but rather to provide a descriptive comparison illustrating how individual physiological responses may differ even when race conditions are similar.

Participants

The participants in this study were two recreational runners who were married partners and voluntarily agreed to participate in the research. Both participants were non-professional athletes and had no medical conditions that would restrict moderate-to-vigorous physical activity. Participation in the study was based on voluntary consent. The selection of participants followed a purposive sampling approach, as the study aimed to examine pacing and physiological responses of two individuals competing in the same race environment. The participants regularly engaged in recreational physical activity but did not have a professional athletic background. Participant characteristics relevant to physiological interpretation, including age, body mass, height, and running experience, were recorded to provide contextual information for the descriptive comparison.

All procedures were conducted in accordance with ethical research principles, and informed consent was obtained from both participants prior to data collection.

Instruments

Data were collected using a Huawei Watch 4 smartwatch, which recorded several performance and physiological indicators during the race. The wearable device provided estimates of running pace, heart rate responses, total race duration, distance covered, and energy expenditure. The smartwatch also generated algorithm-based estimates of maximal oxygen uptake (VO₂Max) and aerobic stress indicators based on heart rate and activity patterns. These metrics were treated as consumer-device estimates rather than direct physiological

measurements, and therefore were interpreted cautiously.

Both participants used the same smartwatch model and monitoring settings during the race to ensure consistency in data recording. Race performance data, including finishing time and pacing information, were obtained from the smartwatch activity records and verified with the official race results when available.

Because the device outputs were generated by proprietary consumer algorithms, VO₂max, energy expenditure, and aerobic-stress values were treated as within-device estimates rather than laboratory-equivalent measurements. The design therefore prioritizes paired, within-event description of pacing and physiological patterns over absolute physiological interpretation.

Procedure

Data collection occurred during participation in the Bukittinggi Police Run 10K road race. Participants ran the same course under identical race conditions. During the race, the smartwatch continuously recorded pacing data, heart rate responses, and other physiological indicators. After the race, activity records were exported from the smartwatch platform for analysis. Kilometer-by-kilometer pacing data and summary physiological indicators were extracted for each participant. Because the study focused on race performance during a single event, only data from the 10 km race were included in the analysis.

Data Analysis

Data were analyzed using a descriptive comparative approach consistent with the small-sample case study design. No inferential statistical analyses were performed due to the extremely limited sample size. Analysis focused on comparing external performance outcomes and wearable-derived physiological indicators between the two participants. Finishing times were compared to

determine the difference in race duration. Heart rate responses were examined through average and peak heart rate values recorded during the race.

Estimated energy expenditure and smartwatch-derived VO_2Max values were descriptively contrasted to illustrate differences in physiological profiles between the runners. Kilometer-by-kilometer pacing data were reviewed to identify variations in pacing patterns throughout the race.

The results were interpreted as descriptive observations intended to illustrate individual variability in pacing and physiological responses during a recreational running event rather than to establish causal relationships or generalizable conclusions.

Findings and Results

Race Completion Time

Race duration provides a direct indicator of overall performance outcomes for the two participants who competed in the same event. In the Bukittinggi Police Run 10K, both runners completed the race with very similar finishing times. The male runner finished the race in 1:29:31, while the female runner completed the course in 1:30:25, resulting in a difference of 54 seconds.

Given the total race duration of approximately 90 minutes, the difference between participants represents a relatively small variation in overall performance time. Both runners completed the same course under identical race conditions. The completion-time comparison is summarized in [Table 1](#).

Table 1

Race Completion Time

Variable	Male	Female
Event	Police Run 10K	Police Run 10K
Duration	01:29:31	01:30:25
Time difference	54 seconds	

Cardiovascular Responses During the Race

Heart rate data recorded by the wearable device indicated different cardiovascular responses between the two participants during the race. The male runner demonstrated an average heart rate of 150 bpm with a maximum heart rate of 177 bpm. In comparison, the female runner showed a higher average heart rate of 165 bpm and a maximum heart rate of 187 bpm. These values indicate that the female runner performed the race at a higher recorded cardiovascular intensity according to the smartwatch data.

Estimated energy expenditure also differed between participants. The male runner recorded a total estimated energy expenditure of 1,011 kcal, while the female runner recorded 774 kcal during the race. Because these metrics were obtained from a consumer wearable device, they represent algorithm-based estimates rather than direct physiological measurements. Heart-rate and energy-expenditure estimates are summarized in [Table 2](#).

Table 2

Cardiovascular and Energy Expenditure Indicators

Variable	Male	Female
Calories	1,011 kcal	774 kcal
Avg HR	150 bpm	165 bpm
Max HR	177 bpm	187 bpm

Estimated Aerobic Capacity

The smartwatch also provided estimates of maximal oxygen uptake (VO_2Max). According to the device output, the male runner had an estimated VO_2Max value of 54 ml/kg/min, while the female runner had an estimated value of 37 ml/kg/min. These values indicate a difference in estimated aerobic capacity between the two runners. Despite this difference, both participants completed the race with similar finishing times. The device-derived aerobic-capacity estimates and race-status data are shown in [Table 3](#).

Table 3*Estimated Aerobic Capacity (VO₂Max) and Race Results*

Variable	Male	Female
Estimated VO ₂ Max	54 ml/kg/min	37 ml/kg/min
Event	Police Run	Police Run
	10K	10K
Race Status	Finish	Finish

Kilometer-by-Kilometer Pacing Profile

Pacing data recorded by the smartwatch provided information on pace variation across the race distance. Both runners demonstrated fluctuations in pace across different kilometers of the course. A noticeable decrease in pace occurred at kilometer 6 for both participants. The male runner recorded 8:16 min/km at kilometer 5, which slowed to 11:48 min/km at kilometer 6, before increasing again to 9:26 min/km at kilometer 7. A similar pattern was observed for the female runner, who recorded 7:54 min/km at kilometer 5, slowed to 11:22 min/km at kilometer 6, and then increased to 9:44 min/km at kilometer 7.

This pattern indicates a temporary pacing slowdown during the middle section of the race followed by a partial recovery in the subsequent kilometer. The complete split profile is reported in [Table 4](#) and visualized in [Figure 1](#).

Table 4*Kilometer-by-Kilometer Pace*

Kilometer	Male	Female
1	7:30	8:07
2	7:28	7:22
3	7:31	7:29
4	8:20	8:18
5	8:16	7:54
6	11:48	11:22
7	9:26	9:44
8	9:42	9:24
9	8:45	8:50
10	10:11	10:34

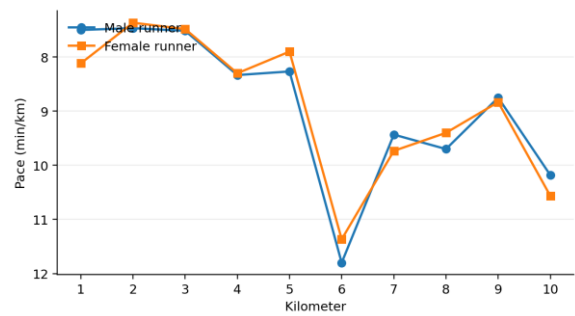


Figure 1. Kilometer-by-kilometer pacing profiles of the two recreational runners. Lower values indicate faster pace.

Environmental Conditions and Aerobic Stress

Both participants ran the same course during the Bukittinggi Police Run 10K, which included elevation changes throughout the route. The maximum recorded elevation during the race was 940.1 m for the male runner and 946 m for the female runner, indicating similar terrain exposure.

The smartwatch also provided an aerobic stress score, with values of 3.7 for the male runner and 4.4 for the female runner. These scores represent device-based indicators of exercise intensity generated by the wearable algorithm. These environmental and device-derived exercise-intensity indicators are summarized in [Table 5](#).

Table 5*Environmental and Aerobic Stress Indicators*

Variable	Male	Female
Elevation Max	940.1 m	946 m
Aerobic Stress	3.7	4.4

Discussion and Conclusion

The findings of this study provide a descriptive comparison of pacing patterns and wearable-derived physiological indicators between two recreational runners participating in the same 10 km road race. Both participants completed the race with relatively similar finishing times, with a difference of 54 seconds, despite differences in several physiological indicators recorded by the wearable device.

The runner with the higher estimated aerobic capacity (VO_2Max 54 ml/kg/min) showed a lower average heart rate during the race (150 bpm), whereas the second participant demonstrated a higher average heart rate (165 bpm) despite having a lower estimated VO_2Max (37 ml/kg/min). Previous research has suggested that although VO_2Max is commonly associated with endurance performance, race outcomes may also be influenced by additional physiological and performance-related factors such as running economy, lactate threshold, and pacing strategy (García-Retortillo et al., 2019; Nikolaïdis et al., 2021; Filipas et al., 2022). The similarity in finishing times observed in this study therefore illustrates how comparable race outcomes may occur even when estimated aerobic capacity and cardiovascular responses differ between individuals (Lundstrom et al., 2015; Nikolaïdis et al., 2021).

Analysis of kilometer-by-kilometer pacing data showed that both runners displayed broadly similar pacing trends across several race segments (Renfree et al., 2020). A noticeable pacing slowdown occurred around kilometer six, followed by a modest increase in pace toward the later stages of the race (Billat et al., 2020). Variations in pacing during endurance running have previously been associated with fatigue development, terrain characteristics, and effort regulation across race segments (Renfree et al., 2020; Costa et al., 2017).

Both participants ran the same course under identical race conditions, which likely exposed them to similar environmental demands (Carbillet, 2019). The recorded maximum elevation values were comparable (approximately 940–946 m), suggesting that terrain-related factors were similar for both runners during the event. Environmental conditions such as elevation changes and terrain variability have been shown to influence running pace and energetic cost during endurance events (Fornasiero et al., 2017; Björklund et al., 2019).

Additional wearable-derived indicators also differed between participants. The runner who exhibited the higher average heart rate recorded lower estimated total energy expenditure compared with the other participant. Such discrepancies may reflect individual physiological responses or differences in device-based estimation algorithms. Previous studies have noted that wearable-derived physiological metrics should be interpreted cautiously, as they are generated through proprietary algorithms rather than direct physiological measurements (Peake et al., 2018).

Recent sport-science work also highlights the value of interpreting athletic performance from multiple physiological indicators rather than from a single metric (Solikah et al., 2026). Likewise, exercise studies demonstrate that individuals can show materially different physiological responses under standardized workloads, reinforcing the need for contextual interpretation of device-derived differences (Pambudi et al., 2026). Accordingly, the observed contrasts in heart rate, energy expenditure, and estimated VO_2max should not be read as evidence that one runner had globally superior physiological efficiency.

Overall, the descriptive comparison illustrates that runners participating in the same race may demonstrate similar overall performance outcomes while displaying different physiological responses according to wearable-derived indicators. However, given the extremely small sample size and the reliance on consumer wearable estimates, these findings should be interpreted as exploratory observations rather than evidence of broader physiological mechanisms.

Strengths and Limitations

A principal strength of this case study is the controlled real-world comparison: both participants completed the same event, on the same course, while using the same smartwatch model and monitoring

settings. Kilometer-level split data also permit the pacing pattern to be examined in greater detail than a finish-time comparison alone.

The limitations are substantial. The sample consisted of only two related recreational runners, so no inferential, sex-based, or population-level conclusions are justified. The report does not provide laboratory VO_2max , direct calorimetry, raw sensor data, or detailed anthropometric and training-history values that would permit physiological normalization. Consumer-wearable estimates may be influenced by proprietary algorithms, body characteristics, wrist-sensor fit, GPS conditions, and device firmware. Weather and kilometer-specific grade data were also unavailable. Future studies should combine larger recreational samples with validated physiological measurements, detailed course and environmental data, and device-validation procedures.

This study provided a descriptive comparison of pacing patterns and wearable-derived physiological indicators between two recreational runners who participated in the same 10 km road race. Although the participants showed notable differences in estimated aerobic capacity and heart rate responses during the race, their finishing times were relatively similar, with only a 54-second difference. These observations illustrate that runners competing under the same race conditions may display comparable overall performance outcomes while experiencing different physiological responses according to wearable-derived indicators.

Pacing data showed a similar pacing fluctuation during the middle segment of the race, particularly around kilometer six, followed by a modest increase in pace toward the later stages. Such variations in pacing have been reported in endurance running events and may reflect the influence of fatigue development, terrain characteristics, or effort regulation during different race segments.

However, these findings should be interpreted

cautiously. The study involved only two participants and relied on physiological estimates generated by a consumer wearable device rather than laboratory-based measurements. Therefore, the results should be considered exploratory and descriptive rather than generalizable.

Future research involving larger samples and more comprehensive physiological measurements may provide a clearer understanding of how pacing patterns and physiological responses interact to shape endurance performance in recreational running events. In practical use, wearable data are most informative when interpreted as complementary trend indicators alongside pacing, athlete history, perceived exertion, and validated physiological assessment rather than as stand-alone diagnostic measurements.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study involved minimal-risk observational use of de-identified race data from two adult participants. Both participants provided informed consent for participation and for the use of their wearable-derived race data. The procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki, and participation was entirely voluntary.

Transparency of Data

By the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors contributed equally to the conception, data interpretation, manuscript preparation, and final approval of the study.

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