

An analysis of resting strategies in ultra-cycling

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Abstract

Background: Pacing is a crucial factor in most endurance sports. In multi-day ultra competitions, the right balance between active effort and rest periods is important. Today, various types of wearable electronic devices are used for this purpose, monitoring the participant's health or locomotion parameters. **Problem Statement and Approach:** During extended multi-day events, the limited battery life of typical electronic devices presents a challenge. The research undertaken is usually based on sporadic checkpoints, because typical sports devices are not designed for such long periods of work. The solution seems to be the use of global navigation satellite systems (GNSS) trackers, which can be set to record position coordinates at specific time intervals, significantly extending their operating time. Since the scientific literature on sports lacks research based on such instruments, this article aims to analyse a selected ultra-endurance event, with particular emphasis on athletes' rest strategies. **Material and Methods:** For the present study, the organiser of Vistula 1200 provided 'gpx' tracks (a universal data exchange format among personal navigation devices) from the 2020 edition, in which 306 participants took part, from which the first 50 were analysed. After exporting the files from the online system, they were imported into an MS Excel spreadsheet, and the duration of cumulative breaks in the ride was determined. **Results:** Statistics of selected participants based on data obtained from their trackers were calculated: stopped and moving time, stop time to total time ratio, mean speed, and number of breaks taken. The results allowed participants to be divided into three groups: first - striving for the best sports performance (first four athletes), second - trying to achieve a good result, but with basic rest/break hygiene (the next 8), and third - the rest, treating the competition as a test of self, a challenge mainly based on distance, not time. The numbers indicated a relatively low athletic level for the event. **Discussion and Conclusions:** It was noted that the best athletes applied breaks of no more than 2 hours, which consumed, at most, 15% of the total time. Half of the participants undertook a maximum of 15 breaks. Most chose to take a longer break on the second night, regardless of whether the finishing time represented 3 or 5 days. GNSS trackers provided valuable material without incurring additional cost for the research and without involving participants directly; however, some of their limitations were noted.

Keywords: Endurance sports; GPS; ultra-events; tactics; pacing strategy; GNSS

Introduction

A common definition of ultra-endurance competitions specifies that they are events with a distance greater than a marathon and lasting longer than six hours. The most popular of these are foot races, cycling, swimming, and triathlons. Regardless of the discipline, they are extremely demanding on the human body (Scheer and Hoffmann, 2020; Brayson et al., 2018; Krokosz et al., 2020; Wołyniec et al., 2020; Rothschild et al., 2021; Gattoni et al., 2025; Méndez-Alonso et al., 2021), mainly due to the distance and time of the effort (e.g., running - UTMB, Ultra Trail du Mont Blanc, 174 km, record slightly over 19 hours; cycling - RAAM, Race Across America, 4800 km, typical winner's time slightly over 7 days). Despite the fact that ultra-events require above-standard athletic endeavour (Spenceley et al., 2017; Knechtle et al., 2022), their popularity has been growing for many years around the world. This is the case for ultra-running (Cejka et al., 2013), ultra-cycling (Tiemeier et al., 2024), and other ultra competitions (Scheer, 2019).

Success, which for many participants is just reaching the finish line, is the result of, among other things, proper preparation, nutrition, hydration, but also rest before and during the effort. The latter begins to be especially important when the distance and time get longer (Knechtle et al., 2012). Then, the total time consists of both movement time and stop time, remaining in interdependence: an athlete who has rested (stop time) is likely to be able to move at a better pace, but this results in increased total time. Finding a balance between these two components of finishing time is crucial during multi-day ultra competitions, when it is physically impossible for a person to complete them continuously without shorter or longer breaks (Schumacher et al., 2011; Netzer, 2021).

Analysis of pace strategy, which in the case of ultra-events is becoming more of a rest strategy, would not be possible without objective, quantitative data (Sha et al., 2024). Today, various types of wearable electronic devices are used for this purpose, monitoring the participant's health or locomotion parameters

(Aliverti et al., 2022). When the first global navigation satellite system (GNSS) - the U.S. GPS NAVSTAR - was made available to civilian users in the mid-1990s, it was not initially envisioned that human movement could be effectively monitored in this way. The receivers were bulky, difficult to use, and not very accurate. However, further developments in this area, as well as the availability of more GNSSs (Russia's GLONASS, Europe's Galileo, and China's BEIDOU), resulted in an increase in the number of devices available on the market, which in turn resulted in an exponential increase in users. Sports and recreational receivers have also evolved (Szot, 2024; Mikos et al., 2024), and their market share is experiencing regular growth (BRI 2025). Participants in ultra events commonly use sport GNSS receivers to monitor movement parameters (pace, time, etc.), their position on the course, and for navigation. Among the most popular types of receivers are those dedicated to particular sports and recreational activities (e.g., Garmin Forerunner series for runners, Garmin Edge series for cyclists) and smartphones. Their accuracy is sufficient for monitoring the locomotion of most users (Specht et al., 2020; Szot et al., 2021), but they are not suitable for recording short or very dynamic changes in position (e.g., short running intervals, playing soccer). In such cases, sports-monitoring devices are equipped with additional sensors, such as accelerometers, gyroscopes, etc., which supplement information about the movement taking place.

Problem Statement and Approach

During multi-day ultra events, monitoring competitors' locomotion becomes an issue. The research undertaken is usually based on sporadic checkpoints (Sha et al., 2024; Heidenfelder et al., 2016), because typical sports devices are not designed for such long periods of work. The solution seems to be the use of GNSS trackers, which can be set to record position coordinates at specific time intervals, thereby significantly extending their operating time. Some long-event organisers equip their athletes with trackers to ensure safety, to verify that participants remain on the desired race route, and for the social aspect (fans can virtually support the "athlete dot" on the map in real time). For researchers, they can be a cost-free solution, providing information about locomotion. Unfortunately, scientific literature on sport lacks analyses based on data obtained from GNSS tracking devices, not to mention the use of this method to determine movement and rest patterns.

Considering the above information and the existing gaps in this research area, this article aims to analyse a selected ultra event and, using data obtained from GNSS trackers, investigate athletes' rest strategies.

The following research questions were posed: (1) Can the activity and rest patterns of ultra-event participants be effectively determined from these devices? (2) Is it possible to distinguish the types of rest patterns undertaken by athletes? (3) To what extent can GNSS trackers be useful for analysing the locomotion of ultra-event participants, and what limitations do they have?

Material & Methods

The event

The data traces of competitors taking part in the "Vistula 1200" (wisla1200.pl) bicycle ultramarathon, which takes place in Poland, were analysed. The route that participants are required to follow runs parallel to the longest Polish river - the Vistula - from its source (the Beskidy mountains, 951 meters above sea level) to its estuary (the Baltic Sea), with the finish line in Gdansk, for a total distance of about 1,200 kilometres, of which only about 25% of the surface is paved. The start is staggered in groups. The competition takes place in a self-supporting formula and lasts non-stop. Any breaks (rests) are decided by the participants themselves and count towards the total time of the race. Typically, winners need about 60-70 hours to complete the route (e.g., 2018 - 62 hours 13 minutes; 2019 - 62:24; 2020 - 59:56; 2021 - 59:53; 2022 - 73:10; 2023 - 54:50; 2024 - 61:18).

Monitoring devices

The organiser equips each participant with a GNSS tracker for safety and monitoring purposes. Athletes, by entering the competition, agree to this regulatory requirement. In 2020, the devices were Queclink GL200 and GL300W, reporting position coordinates every 5 minutes to the online system. Their technical specifications include: weight 60/93 g (GL200/GL300W), dimensions 67x40x21/78x40x27 mm, operating time at 5 min reporting interval 130/90-230 hrs, u-blox All-In-One GPS chipset (both the same), and position accuracy (CEP measure, Novatel 2003) <2.5 m. The recording rate was not high, mainly as a result of the need to ensure the operation of the device over the entire route distance (without additional charging).

Procedure and data analysis

For the present study, the organiser provided 'gpx' tracks (a universal data exchange format among personal navigation devices) from the 2020 edition, in which 306 participants took part, with the first 50 analysed. Due to the fact that this study involves the analysis of data obtained from satellite trackers provided by the organiser and does not directly involve people, the local ethics committee has waived the requirement to obtain additional consent. After exporting the files from the online system, they were first shortened to correspond only to the section between the start and finish. They were then imported into an MS Excel spreadsheet (geographic coordinates, time, distance cumulatively; for the competitor remaining the longest on the route - about 1,400 points), and the duration of cumulative breaks during the race was determined. This analysis revealed that some of the devices suspended their work for a period (a break occurred). If the participant did not move during this time, the data trace was further analysed; if a shift inconsistent with the cycling mode was noted, the trace was discarded. For this reason, 36 data traces (32 male, 4 female) were considered for the final calculation.

Results

Table 1 shows the statistics of selected participants from the top 50 list of finishers based on GNSS tracker data. Analysing the results related to time (columns 2-4), one can see that the first two riders deviate significantly from the others (total time #1 - 59.9 h, #3 - 68.7 h). On the other hand, the last rider (#49) took almost twice as long to complete the route. The shortest stop times (col. 4) were taken by riders #3 and #1 (8.2 and 8.3 h, respectively). Among the others, #12 (16.2 h) and #13 (23.6 h) stand out significantly, with a rather low value of stop time for the place obtained. In percentage terms (col. 5), it is noteworthy that the best athletes spent no more than 15% of their total time on breaks (#3, #1, #4). The longest values were observed in #19, #24, #38, and #42 (from 42.8 to 44.2%), with the vast majority in the 30-45% range (with an average of 32.9 ± 8.3 h). In this group, #12 is a clear outlier at 17.5% (being the first female participant, an athlete with very extensive experience in multi-day ultra competitions). The lowest value of mean moving speed (col. 7) was recorded by participant #43 (13.4 km/h) and the highest by #1 (20.6 km/h).

Table 1. Statistics of selected participants based on data obtained from trackers

1	2	3	4	5	6	7	8	9	10	11	12	13
Place at the finish line	Time (hours)			Stop Time /Total Time (%)	Mean speed (km/h)*		Number of breaks taken					
	Total	Stop	Moving		Total	Moving	≤ 0.5 h	(0.5-2> h	(2-4> h	(4-8> h	> 8 h	Total
1	59,9	8,3	51,6	13,8	17,7	20,6	-	2	1	-	-	3
3	68,7	8,2	60,5	11,9	15,4	17,4	1	3	-	-	-	4
4	78,5	11,8	66,7	15,0	13,5	15,9	5	2	1	-	-	8
5	79,5	20,6	59,0	25,8	13,2	17,8	5	6	-	1	-	12
6	81,7	21,5	60,2	26,3	13,0	17,6	2	2	1	2	-	7
7	85,0	23,4	61,6	27,5	12,3	17,0	6	6	2	-	-	14
9	86,1	25,1	61,0	29,2	12,2	17,2	6	10	-	-	-	16
11	92,0	33,8	58,2	36,8	11,4	18,1	5	4	-	3	-	12
12	92,4	16,2	76,2	17,5	11,5	13,9	1	4	-	1	-	6
13	94,1	23,6	70,5	25,0	11,3	15,1	7	6	1	1	-	15
14	96,6	34,4	62,2	35,6	11,3	17,5	6	3	-	4	-	13
15	97,5	31,2	66,3	32,0	11,0	16,1	4	5	1	-	1	11
17	100,9	32,1	68,8	31,8	10,5	15,4	14	9	2	-	-	25
18	101,3	35,5	65,8	35,1	10,5	16,2	10	12	1	1	-	24
19	101,3	44,8	56,6	44,2	10,3	18,5	7	4	-	2	2	15
20	101,9	37,2	64,7	36,5	10,4	16,3	13	4	-	2	1	20
24	104,3	45,9	58,4	44,0	10,1	18,1	9	7	-	2	2	20
25	105,8	31,4	74,4	29,7	10,1	14,4	1	8	1	2	-	12
26	105,9	42,1	63,8	39,7	10,0	16,5	8	7	1	3	-	19
27	105,9	41,4	64,5	39,1	10,0	16,3	5	6	-	2	1	14
28	105,9	39,7	66,3	37,4	10,0	16,0	5	11	1	1	1	19
29	105,9	33,1	72,9	31,2	10,2	14,8	11	9	2	1	-	23
30	107,0	33,9	73,1	31,7	9,9	14,5	5	4	3	2	-	14
31	107,4	40,0	67,4	37,2	10,0	15,9	4	7	-	4	-	15
32	107,4	40,5	66,9	37,7	9,9	15,9	6	7	-	4	-	17
34	108,8	44,4	64,4	40,8	9,7	16,4	6	4	-	2	2	14
36	110,0	37,6	72,3	34,2	9,7	14,8	5	11	3	1	-	20
37	110,8	41,3	69,5	37,3	9,7	15,4	4	5	-	-	2	11
38	111,6	48,3	63,3	43,3	9,5	16,8	4	2	-	-	4	10
40	111,7	41,3	70,3	37,0	9,5	15,1	4	8	-	4	-	16
41	111,8	40,8	71,0	36,5	9,5	15,0	4	8	1	3	-	16
42	112,2	48,0	64,2	42,8	9,4	16,5	8	3	-	1	3	15
43	113,1	33,5	79,6	29,6	9,4	13,4	6	6	1	2	-	15
47	116,8	41,3	75,5	35,4	9,2	14,3	6	4	-	1	1	12
48	117,4	47,2	70,2	40,2	9,1	15,2	6	8	-	3	1	18
49	117,8	41,8	76,0	35,5	9,1	14,1	11	11	3	3	-	28

* due to the distance underestimated by the trackers (resulting from the recording interval), the mean speed of movement is also underestimated, but equally for all riders (by about 10-12%). However, this does not affect the key characteristics for this article (interactions, proportions, accumulation of breaks).

The relationship between mean moving speed and stop time supplemented by the trend line is shown in Fig. 1. As can be seen, with similar stop time, athlete #1 achieved a higher mean moving speed than athlete #3. In contrast, #19, #11, and #24 moved fast, but this was offset by longer rest times, so they achieved distant places in the analysed group.

Fig. 1. Relationship of stopping time to moving mean speed (points correspond to competitors and their place at the finish line). The dashed line indicates the trend.

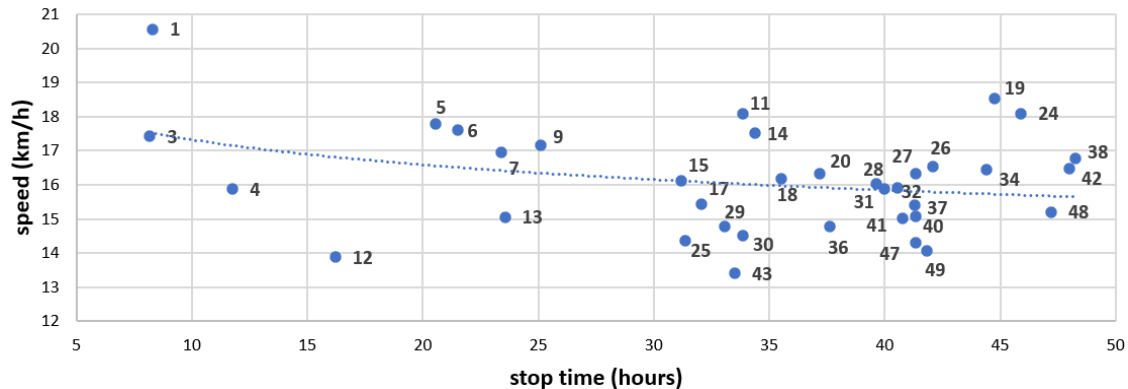
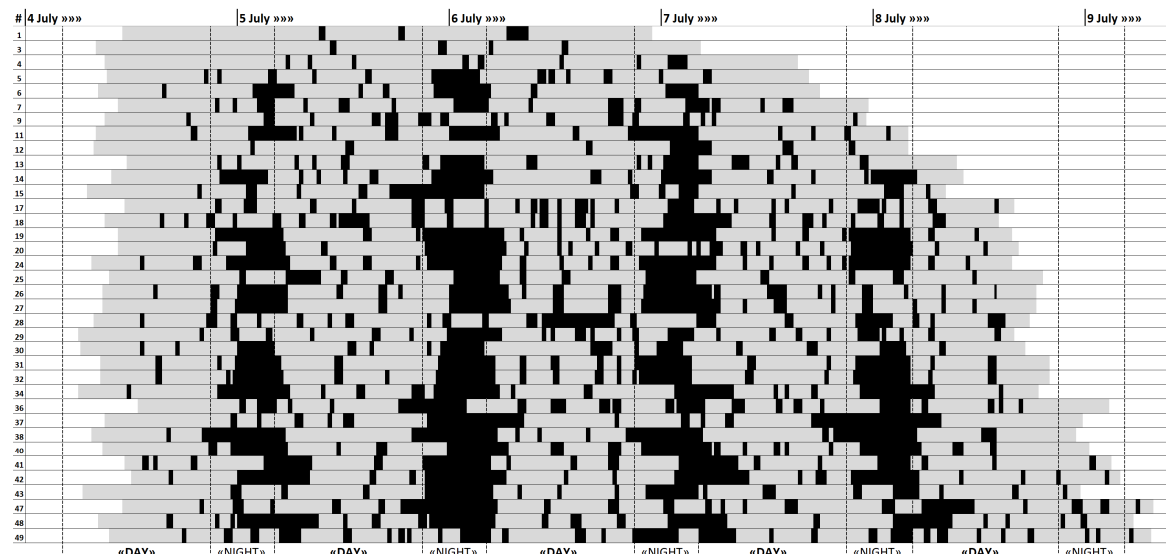


Fig. 2 shows a diagram of the moving and resting periods of the study group (numbers on the left). The grey boxes show the time spent on the route, while the black boxes show the breaks. The upper part of the diagram shows the beginning of the calendar days, while the lower part shows the nights that fall between sunrises and sunsets (dashed lines).

As can quite easily be seen, in the analysed group, the majority opted for a longer break in the ride, falling on the second night (July 5/6), regardless of whether the finishing time represented 3 or 5 days. Throughout the race, at least 4 hours of night breaks were decided on: during the 1st night - 13 out of 36, the 2nd - 25/36, the 3rd - 14/36, the 4th - 11/31, and during the 5th night - 0/10 people. The exception to this is the first three players (#1, #3, #4), none of whom had such a long break. Additional findings from this figure are presented in Table 1, col. 8-13 (break characteristics), arbitrarily setting ranges and counting break occurrences for each of the analysed participants. Among those at the top of the list, very short (up to 0.5 h, col. 8), short (up to 2 h, col. 9), and medium (2-4 h, col. 10) breaks predominate.

The overall number of breaks (col. 13) shows an increasing trend with the position on the list. It is also noteworthy that athletes with a 7-8 hour prospect of appearing at the finish line forgo breaks of more than 2 hours. Such a pattern was noticed in all except #14.

Fig. 2. Moving (riding) and resting diagram of selected participants of the ultra Vistula 1200 event (grey boxes - time spent on the route, black boxes - rest periods)



Discussion

This paper addresses the issue of establishing rest patterns based on GNSS tracker data during one of the longest and most popular ultra-cycling races in Poland. It can be concluded that the main goals were achieved, with some limitations.

It is obvious that when covering such a long distance (approx. 1,200 km), especially when only part of the route is paved, participants do not ride non-stop. The breaks they take are usually caused by the desire to rest (including sleep) and the need to replenish food and drink. They are also sometimes spontaneous, related to road conditions, equipment breakdown, or social aspects. Rest and sleep may fall at different points along the route, as clearly illustrated in Fig. 2, and they can also have different patterns.

Before the present study was undertaken, it was expected that it would be possible to distinguish three groups of ultra-race participants: (A) striving for the best sports performance, even at the cost of health (significantly depleted rest/break times), (B) trying to achieve a good result, but with basic rest/break hygiene, and (C) treating the competition as a test of self, a challenge mainly due to distance (not time). It turned out that in the analysed edition of Vistula 1200 (Tab. 1, Fig's 1 and 2), race group A is quite narrow and ends with competitor #4, group B consists of participants #5-13 (without #12), therefore, the rest (from #14 onwards) are participants entering group C (taking regular, or irregular breaks/rests). The proportions of participants in groups A/B/C indicate that this competition is characterised by a relatively low athletic level, which is probably due to the rather "adventurous" nature of the route (only about 25% on paved roads).

A Netzer 2021 study addressing the topic of rest (specifically - sleep) in ultra cycling noted that although fractured sleep is mostly portrayed negatively, humans can maintain performance with a minimum of sleep. An example was given of a cyclist at the RAAM road race who slept less than 8 hours during the 8.5-day effort, which was divided into 11 short naps (a mean of about 9 minutes) and 6 longer periods of sleep (a mean of about 64 minutes). Despite the significant difference in race duration between RAAM and Vistula 1200, the tactics depicting the distribution and length of riding and rest periods, i.e., no sleep on the first night and short stretches of rest on subsequent days of riding, are also seen in the top riders in this study (#1, #3, and #4, Fig. 2). Other studies, but on multi-day ultra runs, have confirmed that short, <30 min naps are a very popular approach among athletes (Martin et al., 2018, Kishi et al., 2024). Interestingly, although a high prevalence of sleep deprivation symptoms is noted, as well as falls and hallucinations, only 60-80% of athletes use a sleep management strategy before and during the race (Kishi et al., 2024).

Conclusions

The results presented in Tab 1 (col. 8-13) and Fig. 2 allowed us to draw some conclusions related to the patterns of moving (riding) and rest time during the analysed ultra-event: (1) The best riders (#1, #3, and #4) used breaks of no more than 2 h (Fig 2), devoting 15% at most of their total time to them (Tab 1, col. 5); (2) Half of the participants in the analysed group took a maximum of 15 breaks (median from Tab 1, col. 13), and among the first eleven analysed riders (#1-#15), not a single one stopped more than 16 times. (3) Six participants in the analysed group chose to rest regularly every night (Fig. 2, #14, #19, #24, #31, #32, and #38). (4) 13 athletes did not take rests longer than 2h at night if they were to reach the finish line after midnight, or the next day. Their opposite was #14, who undertook a night's rest even though they could have reached the finish line in a few hours (Fig. 2). (5) One can see isolated cases of "strange" rest patterns, e.g., #12 (only one longer break, the third night of the race, Fig. 2) and #47 (longer rests every other night, Fig. 2). (6) In the second half of the analysed group, there are quite a few cases of athletes whose longer night rest shifted to later hours (Fig. 2, #34, #40, #41, #42, and #48). This may be the result of not reaching the scheduled rest area before sunset. To confirm the above patterns, the authors suggest that future studies should cover a larger amount of data (mainly a larger number of editions of the selected ultra-event).

The GNSS trackers used by the organiser to monitor participants in the Vistula 1200 competition proved to be a valuable tool for achieving the objectives set in this article: both models of the devices came from the same manufacturer, they were based on the same GNSS chipset, were set up in the same way and offered a fairly long operating time (at least 4 days). Some riders, knowing their approximate time for the entire route, turned them off during long or very long breaks to extend operation, and when they turned them back on, the trackers resumed operation (in the case of top players, however, this was unnecessary). The set recording interval (every 5 min; in Fig. 2, the values were cumulative, which was also the basis for the break characteristics in Table 1, col. 8-13) proved sufficient to determine riding and resting patterns. On the other hand, during the analysis of the routes of the first 50 participants, several problems with trackers were encountered: long breaks in recording were noticed, during which a longer distance was covered (probable reason: the participant forgot to turn on the receiver while resuming driving after a long break; such traces were discarded); short breaks in recording were noticed, during which the receiver did not register the displacement or it was insignificant (probable reason: a temporary interruption in access to navigation satellites, resulting from entering some object, e.g., store, gas station, etc.; in each such case it was decided individually whether the interruption could be included in the analysis) and it was noted that despite a fixed recording interval, sometimes other values appeared, e.g., 2, 4, 6 min (probable reason: errors in software). To eliminate these drawbacks, the authors suggest that in future, trackers to be used for accurate locomotion analysis should be tested in advance, in

accordance with the appropriate methodology (Specht et al., 2019a; Szot et al., 2019; Specht et al., 2019b; Szot & Sontowski, 2024).

Amateur sports, which play an important role in the life of developed societies, have the fact that they do not take place under as much control as professional sports. This applies to training, supplementation, and monitoring of the body's functional parameters. It happens that amateur participants making efforts beyond their capabilities suffer periodic or permanent damage to their health. According to the authors, this indicates the need to make participants in multi-day ultra events aware that, in addition to focusing on pace, nutrition, and hydration, a proper rest strategy during the competition is also an important element for staying healthy.

Conflicts of interest

The authors declare that there is no conflict of interest.

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Declaration of generative AI and AI-assisted technologies in the writing process

The authors declare that they did not use any AI-based tools to prepare this article.

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