Journal of Physical Education and Sport ® (JPES), Vol. 23 (issue 7), Art 216, pp. 1762 - 1773, July 2023
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Physical effort and pace of MTB and eMTB bicycles on mountain trails - a case study

ANDRZEJ OSTROWSKI[1], ARKADIUSZ STANULA[2], TADEUSZ AMBROŻY[3], ŁUKASZ RYDZIK[4] ALEXANDER SKALIY[5] DARIUSZ SKALSKI[6], KRZYSZTOF KAGANEK[7], KATERYNA MULYK[8].
[1]Department of Water Sports, Academy of Physical Education, 31-571 Krakow, POLAND;
[2]Institute of Sport Sciences, Jerzy Kukuczka Academy of Physical Education, 40-065 Katowice, POLAND;
[3,4]Institute of Sport Sciences Academy of Physical Education, 31-571 Krakow, POLAND;
[5]Institute of Sport and Physical Culture, University of Economy, 85-229 Bydgoszcz;
[6]Department of Swimming and Water Rescue, Academy of Physical Education and Sport 80-336 Gdansk, POLAND;
[7]Department of Coaching and Innovation, Faculty of Tourism and Recreation, Institute of Entrepreneurship and Management, University of Physical Education, 31-571 Krakow, POLAND
[8] Kharkiv State Academy of Physical Culture, 61058 Kharkiv, UKRAINE;

Published online: July 31, 2023
(Accepted for publication July 15, 2023)
DOI:10.7752/jpes.2023.07216

Abstract:
This scientific article presents the intriguing results of a comparative study on the performance and effort parameters in mountain biking (MTB) and electric mountain biking (eMTB). The study meticulously involved a 51-year-old male participant boasting a normal BMI and excellent aerobic fitness. Both MTB and eMTB were subjected to rigorous testing, with designated mountain trails chosen for the rides. Heart rate monitoring, facilitated by specialized equipment like the Garmin Edge 1030 bike computer and the Garmin HRM Pro chest strap, meticulously recorded effort parameters. All the gathered data was securely stored and subjected to meticulous analysis in the Garmin Connect cloud.The comprehensive findings disclosed that the total riding time on the mountain trail was remarkably 45.3% longer on the traditional MTB compared to the eMTB. However, the eMTB demonstrated a noteworthy 31% higher average speed, particularly evident during challenging uphill sections and minor inclines. This discovery implies that eMTB riding provides a time-saving advantage while delivering a thrilling and faster-paced experience.Interestingly, despite the significant disparity in average speed, no statistically significant differences were observed in maximum speed between the two bike types. This suggests that both MTB and eMTB are capable of reaching similar peak speeds, ensuring exhilarating moments for riders irrespective of their chosen bike.When examining the effort parameters measured through heart rate, it was found that the average heart rate (HRAVG) during MTB riding was approximately 11% higher than during eMTB riding. This highlights that traditional MTB demands more intense cardiovascular effort and physical exertion.Similarly, the maximum heart rate (HRMAX) during MTB riding was slightly higher, though the difference was not statistically significant compared to eMTB riding. This suggests that both forms of biking can push participants to similar maximum heart rates despite the varying average heart rates.In conclusion, this insightful study adds valuable evidence to the ongoing discourse around MTB and eMTB riding. The results underscore the advantages of eMTB riding, offering faster speeds and higher average speeds compared to traditional MTB. Moreover, the study brings to light the comparable maximum speeds between the two forms of biking. The heart rate-based findings are crucial for mountain biking enthusiasts as they contemplate the best-fit option between a traditional mountain bike and an electric mountain bike, based on their preferences, physical capabilities, and desired riding experience.
Key Words: **mountain biking, electric mountain biking, performance, effort parameters, heart rate monitoring**

Introduction

Promoting physical activity is a global public health priority. The World Health Organization's guidelines for adults (18-64 years) recommend engaging in physical activity for 150-300 minutes/week of moderate intensity or 75-150 minutes/week of high intensity (WHO 2021).
One form of physical activity is bicycle tourism, which takes into account such elements as travel, active recreation and sightseeing (Niezgoda 2012, Meyer 2015), in which the means of transport is the bicycle (Dębowska-Mróz et al. 2018). About 70% of Poles ride a bicycle (Kaminska, Wilk-Grzywna 2015). Bicycle tourism (48.0%) is in second place in popularity, just after hiking - 51.0% (Pieniążek et al. 2016). Thus, it is one of the most popular forms of physical activity, undertaken individually or in a group (Bartoszewicz 2011, Zatoń and Zatoń 2014, Smolarski 2015,). The advantage of using the bicycle for tourism is the combination of

Corresponding Author: ŁUKASZ RYDZIK, E-mail: lukasz.rydzik@awf.krakow.pl

communing with nature, direct contact with other people, shaping motor skills and physical fitness with the possibility of penetrating areas inaccessible by car at nearly four times the speed of travel than on foot (Beim 2012). Bicycle touring can be done individually or in groups, in one day starting and ending at the place of residence or with the need to reach the chosen route by other means of transport, and multi-day with overnight stays (http://www.aktivtour.pl, http://www.zdrowy-rower.pl/).

Motives for bicycle tourism include physical activity (37.0%), relaxation, rest (27.0%), hobby and passion (26.0%), making new friends (19.0%) sightseeing (18.0%), communing with nature (14.0%), desire to improve health (13.0%), experiencing strong sensations and competition - 9.0% (Pieniążek et al. 2016). The prospects for the development of bicycle tourism because of the accessibility to attractive places, the ease of buying, renting a bicycle, the feeling of freedom and independence are high and will increase (Borawska-Melnyk 2016).

Cycling improves endurance, strength of the muscles of the legs, trunk and arms, efficiency of the respiratory and circulatory systems. As a result of increased metabolism, there is weight loss, a reduction in the level of "bad" cholesterol, and an increase in "good" cholesterol, the secretion of so-called "happiness hormones" (endorphins), associated with aesthetic experiences, which consequently improves well-being, bringing joy (Dębowska- Mróz et al. 2018).

It has been proven that the result of an hour of cycling, depending on the pace, body composition and weight, type of bicycle, terrain, weather, etc., there is an energy expenditure of 300 to 800 calories, this is less than that of continuous running, but cycling is more safe for the musculoskeletal system, especially for people who are overweight or have very little physical activity, or periorbital pain. Regular cycling exercise, dosed in the right dose, regulates blood glucose levels. To achieve the desired health effects, cycling should be done at least three times a week for 30-40 minutes each (www.centrumrowerowe.pl.)

In planning a bicycle tour, the main thing to keep in mind is the choice of route, appropriate to your needs, expectations and abilities. Be stocked with fluids and foodstuffs. It is especially important to regulate hydration, as dehydration of as little as 2.0% of body weight results in a decrease in performance by up to 20.0%. In cycling, the exertion, and therefore dehydration, is less noticeable, as the rush of air dries the skin and sweating is not felt as much as, for example, when running (https://www.centrumrowerowe.pl).

Cycling is recommended for most of the population, especially for overweight and obese people, those with sedentary lifestyles, overworked and stressed, those with knee joint problems and osteoarthritis, those struggling with insomnia and those with limited opportunities for other forms of exercise. Cycling is an excellent form of rehabilitation and correction of the lower extremities. (https://portal.abczdrowie.pl).

One form of bicycle tourism is mountain biking, classified as an aerobic physical activity. It is designed for people who have relatively highly developed motor characteristics, good fitness and fitness preparation. It involves being in a natural environment with simultaneous sightseeing, using a mountain bike called MTB (Mountain Terrain Bike) to move along the trail.

Mountain biking is of interest to more and more people (Wiesner et al. 2016). Motives for mountain bicycle tourism include the desire to enjoy the views, urbanism, at different times of the day, year, climbing peaks, completing routes, off-road trails, individually or in groups, testing one's own technical, fitness, or motor skills. In mountain biking, unlike mountain biking, there is no competition, which means that participants choose their own equipment, clothing, time, effort and rest periods. It is also up to them to plan the route, its degree of difficulty, intensity of effort, rest, selection of co-participants, etc.

Mountain biking always involves risks (Wiesner, 2011). The safety of mountain biking is determined by differences in altitude, terrain, weather conditions, variability of the ground and predisposition, the behavior of the tourist himself, the technical condition of the bicycle and personal equipment. It can be a source of various types of injuries, as 63.0% of respondents confirmed. Despite this, only 18.5% of respondents use any protection, most often a helmet and elbow and knee pads (www.siroko.com). Health restrictions should also be kept in mind when practicing mountain biking. It should be avoided or people with severe cardiovascular disease, chronic obstructive pulmonary disease, advanced musculoskeletal disease, vagus disease, and a very difficult-to-correct visual impairment that limits free vision (www.centrumrowerowe.pl) should consult a sports doctor before joining.

Routes for bicycle tourism are specially designated and prepared areas in attractive scenic terrain, marked with unified road signs, constituting an optimal determinant of possibly safe wandering to the designated destination, tourist and sightseeing objects (Jackowski, Jaruzalski 2012). Two main types of routes are distinguished: separated, i.e. separated, both along the main routes and outside them as bicycle roads and pedestrian and bicycle routes, as well as bicycle lanes created on public roads, combined with motorized traffic, with facilities in the form of sergeants painted on the roadway, locks, shortcuts at intersections, with permission to ride on busways or against traffic on one-way streets, and with the designation of so-called. tempo 30 zones or indicating roads with low traffic volumes, such as the EuroVelo model (Pisarska, Pisarski 2012, Dębowska-Mróz et al. 2018).

A cyclist-friendly route must be safe and comfortable, separated, and if not, lead along roads with low car traffic, be equipped with good accommodation, catering, information infrastructure. Its route is to provide convenient access by individual and public transport (Niezgoda 2012, Kolodziejczyk, Kalewicz 2015, Meyer,

Sawinska 2018,), since most cyclists (55.5%), live too far from bicycle routes ((Kłos-Adamkiewicz 2015, Debowska et al. 2018). Bicycle-friendly facilities use new technologies like GPS, smartphone web apps, such as Strava. Websites provide information about bicycle routes with maps, such as http://www.traseo.pl.
Routes for mountain biking are designated areas, with selected distances, elevations and degrees of difficulty of the terrain, meeting the safety requirements of their users through signage, the quality of the ground and the protection of the edges (Pieniążek et al. 2016). The high quality of these routes increases the level of comfort and satisfaction of riders. The local government or cooperating associations or business entities are responsible for their designation and supervision. Routes for mountain biking are usually well described in guidebooks, brochures, phone apps, so it is easy to determine the planned climbs, descents, tour time. All route descriptions are written from the perspective of riding a MTB mountain bike, without electric assistance (www://beskidyrowerem.eu) .

In visiting attractive areas, mountain bikes, commonly referred to as MTB (Mountain Terrain Bike), are the primary means of transportation (82.8%). This is followed by tourists going to the mountains by car (58.6%) or on foot - 53.9% (Kozak 2019). Mountain bikes have been designed and refined for more than four decades. They are distinguished by their safe, often shock-equipped pneumatic design, with wide rims and tires and a multi-gear system. They are characterized by specific design of frame, saddle, gears, derailleurs, disc brakes or suspension (http://www.ppc.webserwer.pl). Currently, Hardtail mountain bikes dominate (59.0%), equipped with a front-wheel shock absorber, generally lighter and better equipped (https://pl.wikipedia.org/wiki/Hardt than with full suspension - 16.0% (Wiesner et al. 2016). MTB mountain bikes are characterized by their versatility, huge selection, wide price range and durability of parts, making them among the most popular. MTB frames can be rigid or suspension, wheels: 26, 27.5 and 29 inches, drivetrain with one or two crank discs and 11 or 12 gears in the rear wheel, with a total of 12 to 22 gears.

Electric motor-assisted mountain bikes, known as eMTBs, provide opportunities for mountain biking for a larger population. They therefore represent an attractive and acceptable tool for increasing activity levels in the mountains (Chaney et al. 2019). The eMTBs support riding and are classified according to certain functions and options (Table 1).

Table 1 Characteristics of power steering operation in eMTBs

e-MTB classes	Driving speed when power steering is activated km/h	Equipped with a throttle	Pedaling requirement for enabling support
Class 1	25-32*	Not	Yes
Class 2	25-32*	Yes	Not
Class 3	45-48*	Not	Yes

*After the speed limit indicated by the manufacturer. Source: MacArthur et al. (2014)

The research problem related to the differences in the use of MTB and eMTB mountain bikes due to the novelty of the latter has been limited until now, but it has been increasingly addressed for several years. The first publications considered whether electric-assist bicycles are a cause of environmental degradation, especially of reverently prepared mountain bike trails (https://b.3cdn.net/bikes/d4d3792f3643272682_2nm6b4ec8.Pdf, https://b.3cdn.net/bikes/c3fe8a28f1a0f32317_ g3m6bdt7g.pdf.) Safety aspects related to the ability to drive faster over difficult, varied terrain were further studied (Feng et al. 2010, Langford et al. 2015). The largest part of the research was related to the quality and variety of effort, which was lower in eMTB riders (Simons et al. 2009, Gojanovic et al. 2011), but high enough to reach the standards of health-promoting moderate-intensity physical activity (Simons et al. 2009, Louis et al. 2012) . Consequently, heart rate and oxygen consumption were also lower during the ride (Berntsen et al. 2017). The ability to stimulate with exercise has been shown to improve metabolism, including glucose regulation (Peterman et al. 2016), which promotes better well-being (Sperlich et al. 2012). Results have also argued for the potential of eMTBs to be used by broader populations, as they can be ridden without excessive fatigue over longer distances (Gojanovic et al. 2011, Hoj et al. 2018), even with lower physical fitness and lower motor skills or movement limitations (Blumenstein et al. 2014, Twisk et al. 2017).

The purpose of the study was to determine the differences in the pace of the ride and in the physical exertion during the maximum speed of the same route in a mountainous area riding an MTB and an eMTB. Accordingly, the following research questions were posed:

1. What were the characteristics of the mountain trail rides of MTB and eMTB bicycles in terms of riding pace and physical exertion as measured by heart rate (HR)?
2. What were the differences in pace and physical effort in unassisted and electric-assisted mountain biking on each section of the mountain trail?

Material and methods

The study was conducted by the study's co-author: a man aged 51, Caucasian, weight 85 kg, height185 cm, with a normal BMI of 24.84, regularly (3-4 times a week) engaged in recreational physical activity (cycling, running, swimming). His aerobic capacity (oxygen ceiling) estimated from the Garmin app during the study period was 47 ml/min/kg, which is excellent, close to excellent (https://www8.garmin.com/manuals/webhelp/fenix6-6ssport/PL).

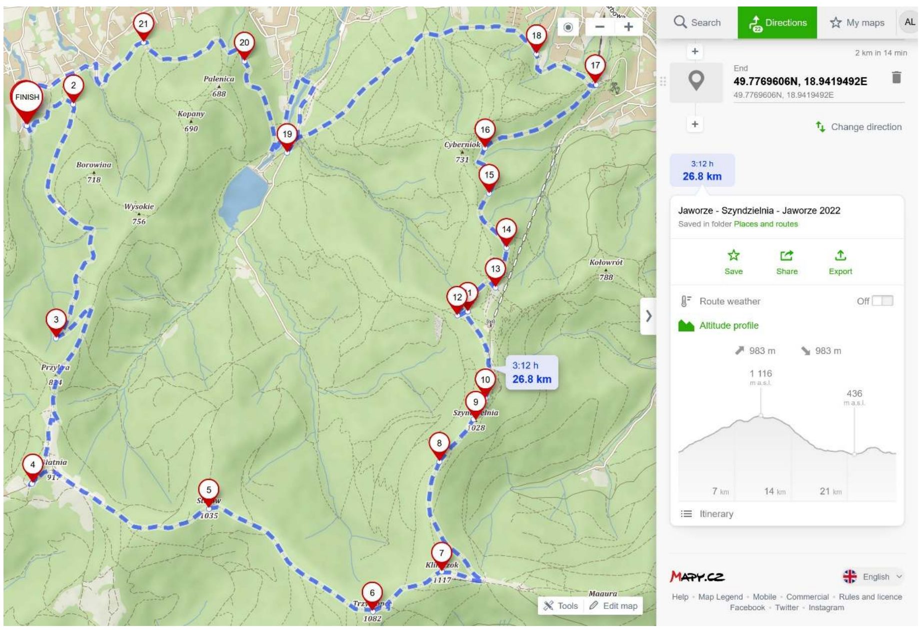
The study was conducted on bicycles:

1) MTB - November 1, 2022 from 10:30 a.m. to 2 p.m. Ride characteristics were obtained from the Garmin Connect app.
2) eMTB - 31/10/2022 from 10:30 a.m. to 12:11 p.m. Ride characteristics were obtained from the eBike Connect Bosch app.

Test site

The characteristics of the bicycle route on the basis of the MAPY.CZ PC application are shown in Photo 1. The route of the ride was determined using the MAPY.CZ Windows-based application. The screen view presented below shows the landmarks (left) and the elevation profile and mileage of the route (right).

Photo 1. Characteristics of the bicycle route based on the PC application MAPY.CZ



Testing equipment

For the study, 2 mountain bikes were used:

1) KTM Myroon Master 12 - 2019 model. - without electric assistance,
2) KTM Machina Kapoho Master - 2021 model. - With electric assistance.

Their characteristics are shown in Photo 2.

<table>
<tr><th>Frame</th><th>Myroon 29" light Sonic Carbon | Hardtail, Boost 148TA</th></tr>
<tr><td>Fork</td><td>Fox 32 A Float SC, Perf. GripRem.- T-15x110</td></tr>
<tr><td>Brake</td><td>Shimano Deore XT M8000 / Rotor 160-160</td></tr>
<tr><td>Rear deraill.</td><td>Sram RD X01 Eagle | 1 x 12</td></tr>
<tr><td>Crankset</td><td>Sram FC X1 Eagle-B148-DUB, Carbon 34T</td></tr>
<tr><td>Sprocket</td><td>Sram CS GX Eagle XG1275-12 | 10-50</td></tr>
<tr><td>Wheel: front, rear</td><td>KTM Comp CC 29" Boost TLR DT Swiss / straightpull - Boost 110/148</td></tr>
<tr><td>Tire: front</td><td>Schwalbe Racing Ray 57-622, s-skin, TL-easy, addix-speed</td></tr>
<tr><td>Tire: rear</td><td>Schwalbe Racing Ralph 57-622, s-skin, TL-easy, addix-speed</td></tr>
<tr><td>Seatpost</td><td>KTM Team SP-619K 27.2/400</td></tr>
<tr><td>Weight</td><td>9,9 kg</td></tr>
</table>

<table>
<tr><th>Frame</th><th>Macina Kapoho Dimmix Performance Carbon SLL-LTE 160m</th></tr>
<tr><td>Fork</td><td>FOX 36 Float 29" Performance e-bike 160mm</td></tr>
<tr><td>Brake</td><td>Shimano Deore XT M8100 / M8120 | 203 mm / 180 mm</td></tr>
<tr><td>Rear deraill.</td><td>Shimano Deore XT M8100-12 SGS shadow+ | 1 x 12</td></tr>
<tr><td>Crankset</td><td>KTM TRAIL ISIS 160mm Q16, FSA Megatooth steel 38T Direct Mount</td></tr>
<tr><td>Sprocket</td><td>Shimano Deore M6100-12 | 10-51</td></tr>
<tr><td>Wheel: front, rear</td><td>Ambrosio E30 Trail 28H 622x30T, Ambrosio E35 Trail 28H 584x35TC</td></tr>
<tr><td>Tire: front</td><td>Maxxis Minion DHF 3C-MaxxTerra/EXO/TR 63-622 (29 x 2.5)</td></tr>
<tr><td>Tire: rear</td><td>Maxxis Minion DHR II 3C-MaxxTerra/EXO/TR 70-584 (27.5 x 2.8)</td></tr>
<tr><td>Seatpost</td><td>KTM Comp dropper internal</td></tr>
<tr><td>Weight</td><td>24,2 kg</td></tr>
</table>

Photo 2. characteristics of MTB and eMTB mountain bikes

Research method

1. Speed test of MTB and eMTB bikes on a designated mountain route
2. Measurement of physical exertion as measured by heart rate (HR) contractions while riding a designated MTB and eMTB mountain bike route.

Research tools

The research tools are presented in Photo 3.

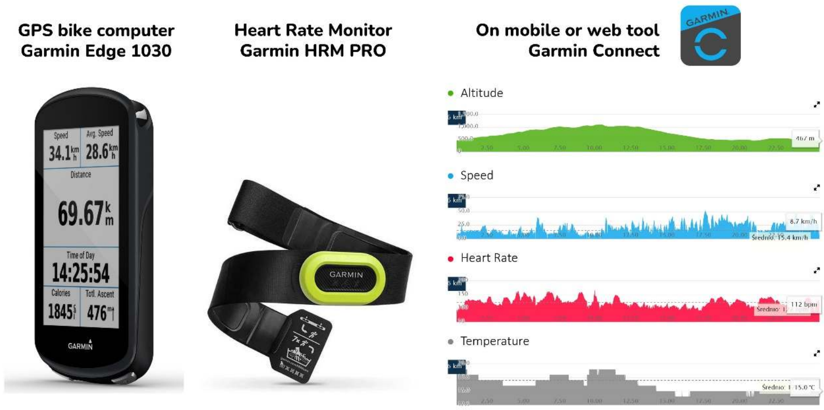


Photo 3. Test tools to measure driving pace and exercise as measured by heart rate (HR) contractions

A Garmin Edge 1030 bicycle counter, paired with a hub-mounted and properly calibrated Garmin Bluetooth Ant+2 speed sensor, was used to measure pace, distance and altitude. A Garmin HRM Pro sensor worn on the subject's chest, paired with the Garmin Edge 1030 bicycle counter, was used to measure physical exertion as measured by heart rate (HR). The recorded data after each ride was saved in the Garmin Connect software cloud, from where it was further exported to a file with the "tcx" extension, containing detailed ride information with a recording interval of 1 second. Conversion of the file with the "tcx" extension to an editable form in an MS Excel spreadsheet was done using GoldenCheetach-Cycling Power Analysis Software v. 4012.

For analysis of exercise measured by heart rate (HR), recorded HR values were classified according to HR zones determined automatically by the Garmin Connect app on the basis of self-detected HR_{MAX} , lactate thresholds and resting HR during an exercise test performed one week before the study.

Designated effort zones (https://running.trigar.pl/)

Zone 5: >161 bpm - maximum

Zone 4: 154-160 bpm - threshold

Zone 3: 144-153 bpm - aerobic

Zone 2: 130-143 bpm - calm

Zone 1: 104-129 bpm - warm-up

Zone 0: below 104 bpm - resting, non-sporting activity

Statistics

The time spent in specific zones of exertion as measured by heart rate (HR) contractions (HR) for each stage of the ride was measured and counted in seconds, and given in h:mm:ss and as a percentage of the total time spent in a given zone of the ride. Differences were calculated by subtracting the MTB to eMTB cycling time, while the last column calculated the difference in percentage, indicating how much more or less time the subject spent in a given riding zone.

Test results

1. General characteristics of the MTB and eMTB mountain bike route ride

The general characteristics of exercise-related parameters measured by heart rate (HR) contractions of MTB and eMTB cycling are shown in Table 2,3 and Figure 1,2. The analysis was made considering individual sections of the mountain route, i.e. uphill, downhill, short descents and ascents, and as a whole.

Table 2. parameters of the MTB mountain bike route.

Parameters	Clumbing	Downhill	2-nd clumb&down	Entire activit
HR_{AVG}	147,7	121,4	138,0	139,8
HR_{MAX}	172,0	158,0	162,0	172,0
$Speed_{AVG}$	7,3	18,7	13,2	10,9
$Speed_{MAX}$	28,9	51,7	50,7	51,7
Time (h:mm:ss)	1:23:25	0:34:14	0:14:48	2:12:27
Distance (km)	10,116	10,660	3,258	24,034

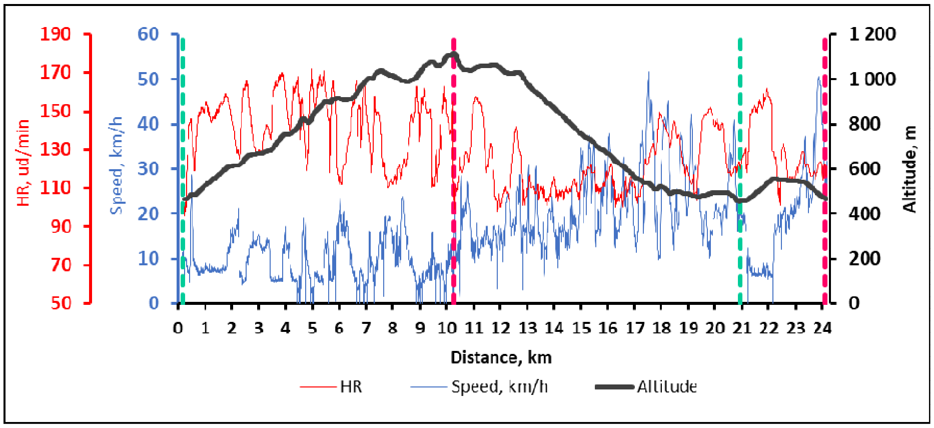


Figure 1. Average physical exertion measured by heart contractions (HR) and MTB cycling rate of each section of the mountain route

It took the respondent 2 hours 12 minutes and 27 seconds to complete the MTB mountain bike route, (Table 2, Figure 1)amounting to 24.034 km. The uphill and downhill sections were of similar length and amounted to just over 10 km. The section with minor ascents and descents was 3.258 km and was covered in 14 min 48 sec. For the uphill section, the respondent took 1 hour, 23 minutes and 25 sec, while for the downhill section, far less, or 34 minutes, 14 sec. The average speed along the entire route was 10.9 km/h, being lowest on the ascent (7.3 km/h) and highest on the descent (18.7 km/h). Despite the average speeds measured on the individual sections, their maximum values were also studied, and were highest on the downhill (51.7 km/h) and sections with light ascents and descents (50.7 km/h), and lowest on the uphill (28.9 km/h). Average Average effort measured by heart contractions (HR_{AVG}) over the entire route was 139.9 bpm and was highest on the uphill, reaching 147.7 bpm, while it was lowest on the downhill, at 121.4 bpm. Physical effort, as measured by heart rate (HR) contractions in all sections, was variable, resulting in its maximum values (HR_{MAX}), over the entire route, reaching 172.0 bpm on the ascent, decreasing on the descent to 158.0 bpm.

Table 3. Parameters of mountain route travel by eMTB bicycle

Parameters	Clumbing	Downhill	2-nd climb&down	Entire activit
HR_{AVG}	131,6	113,1	118,6	124,4
HR_{MAX}	166,0	148,0	142,0	166,0
$Speed_{AVG}$	11,2	22,6	20,0	15,8
$Speed_{MAX}$	39,3	52,2	46,2	52,2
Time (h:mm:ss)	0:49:12	0:26:37	0:09:56	1:25:45
Distance (km)	9,954	10,532	3,441	23,928

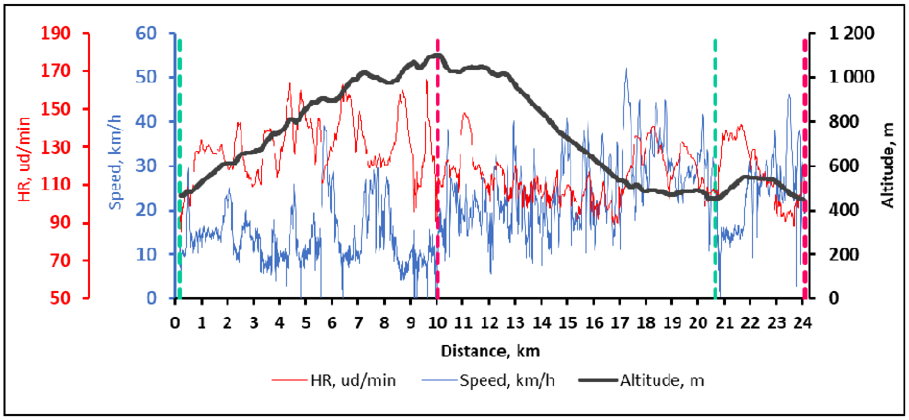


Figure 2. Average physical effort measured by heart rate (HR) contractions and eMTB cycling pace of each section of the mountain route

It took the respondent 1 hour 25 minutes and 45 seconds to ride an eMTB bicycle over a mountain route (Table 3, Figure 2) of 23.928 km. The uphill section was slightly shorter (9.954 km), and the downhill section was slightly longer (10.532 km). The section with small climbs and descents was 3.441 km and was covered in 9

min and 56 sec. For the uphill section, the respondent needed 49 min and 12 sec, while for the downhill section, significantly less, or 26 min, 37 sec. The average speed over the entire route was 15.8 km/h, being lowest on the ascent (11.2 km/h) and highest on the descent (22.6 km/h) and on sections with small ascents and descents (20.0 km/h). Despite the average speeds measured on each section, their maximum values were also studied, which were highest on the downhill (52.2 km/h) and on sections with slight climbs and descents (46.2 km/h), and lowest on the uphill (39.3 km/h). The average physical effort measured by heart contractions (HR_{AVG}) over the entire route was 124.4 bpm and was highest on the ascent, reaching 131.6 bpm, while it was lowest on the descent - 113.1. Physical effort measured by heart contractions (HR) in all sections was variable, resulting in its maximum values (HR_{MAX}) over the entire route, reaching 166.0 bpm on the ascent and decreasing to 148.0 bpm on the descent.
The results obtained in both runs of the mountain route were the basis for determining the magnitude of differences in the parameters studied, which are shown in Table 4.

Table 4. Differences in the parameters of the MTB to eMTB mountain bike route.

Parameters	Clumbing		Downhill		2-nd clumb&down		Entire activity	
	Difference	**%**	**Difference**	**%**	**Difference**	**%**	**Difference**	**%**
HR_{AVG}	+16,1	10,9	+8,3	+6,8	+20,0	+14,1	+15,4	+11,0
HR_{MAX}	+6,0	3,5	+10,0	+6,4	+20,0	+12,3	+6,0	+3,4
$Speed_{AVG}$	-3,9	34,2	-3,9	-17,3	-6.8	-34,0	-4,9	-31,0
$Speed_{MAX}$	-10,4	-26,5	-1,5	-1.0	+4,5	+10,8	-0,5	-1,0
Time (h:mm:ss)	+0:35:13	+42,0	+0:07:37	+22,5	+0:04:52	+51,0	+0:40:42	+45,3
Distance (km)	+0,162	+1,6	+0.134	+1,2	-0,183	-5,3	0,106	+0,5

The biggest difference was observed in the time taken to ride the entire mountain route, which took 45.3% longer with the MTB bike than with the eMTB bike. Differences in this parameter were noticeable on every section of the mountain route. The opposite of the time it took to complete the route was the average pace of the route, which was 31.0% higher with the eMTB bike, especially on the ascent and on minor climbs and descents, settling at 34%. Despite the significant differences in the average pace of the ride, there were no similar differences in the maximum speeds over the entire route, which were similar in the respondent's rides with both bicycles, despite the decidedly, up to 26.5% faster pace on uphill rides with the eMTB bike. Analyzing changes in exercise, there were no significant differences, despite higher average values, reaching from 8.3% to 14.1% in the respondent during the MTB bike ride. The differences were even smaller in terms of maximal exertion measured by heart contractions (HR_{MAX}), where the average difference over the entire route was 3.4%, reaching the highest value (12.3%) on small climbs and descents.

2. Differences in BMT and eBMT mountain biking with effort zones measured by heart rate (HR) contractions - uphill

Differences occurring in the time taken to ascend a mountain trail by MTB and eMTB bicycle, taking into account the effort zones measured by heart rate (HR) contractions, are shown in Table 5.

Table 5. Zones of effort and their differences occurring during a mountain bike MTB and **eMTB** ascent

Zones of effort -. Clumbing	MTB		eMTB		MTB vs eMTB (h:mm:ss)	MTB vs eMTB (%)
	t (h:mm:ss)	**t (%)**	**t (h:mm:ss)**	**t (%)**		
Zone 5 | Maximum > 161	0:18:29	22,2	0:01:06	2,2	0:17:23	+94,0
Zone 4 | Thershold 154-160	0:15:54	19,1	0:06:48	13,8	0:09:06	+56,2
Zone 3 | Aerobic 144-153	0:24:01	28,8	0:04:32	9,2	0:19:29	+81,1
Zone 2 | Easy 130-143	0:12:00	14,4	0:12:24	25,2	-0:00:24	-3,3
Zone 1 | Warm Up 104-129	0:12:34	15,1	0:22:24	45,5	-0:09:50	-43,9
Zone 0 | Below<104	0:00:27	0,5	0:01:58	4,0	-0:01:31	-77,12
Total	**1:23:25**	100,0	**0:49:12**	100,0	0:34:03	+70,6

With an MTB bicycle climb of 1 hr, 23 min and 25 sec, the respondent spent the longest time in effort zone 3 (28.8% of the total climb time). This was followed by effort zone 5, with 22.20% of the total climb time, and effort zone 4, with 19.1% of the total climb time. For a slightly smaller period of time, the respondent stayed in effort zone 2 - 14.4% of the total climb time and effort zone 1 - 15.10% of the total climb time.
For an eMTB bicycle ascent lasting 49 min and 12 sec, the subject stayed primarily in effort zone 1 (45.50%), and effort zone 2 (25.2%). He spent between 2.2% and 13.8% of the total climb time in the other effort zones 3,4,5. The MTB bike climb was 34 min and 03 sec longer than the eMTB bike.

Analyzing the differences in residence time in the different effort zones, it was noted that the respondent riding the MTB bike definitely stayed longer in the effort zones 5,4,3, while riding the eMTB bike in the other effort zones, namely 2,1 and 0.
During the MTB bicycle climb, taking 70.6%% longer than the eMTB, the largest percentage differences between residence times in each effort zone were noted in effort zone 5, where the respondent riding the MTB bicycle was 94.0% larger than riding the eMTB bicycle. Riding the MTB bicycle also had longer residence times in effort zone 3 (by 81.1%) and effort zone 4 (by 56.2%), and shorter residence times of 43.9.1% in effort zone 1.

3. Differences in BMT and eBMT mountain biking with effort zones measured by heart rate (HR) contractions - downhill

Differences occurring in downhill MTB and eMTB mountain bike time with effort zones measured by heart rate (HR) contractions are shown in Table 6.

Table 6. Effort zones and their differences occurring during downhill MTB and **eMTB** mountain biking.

Zones of effort -. Downhill	**MTB**		**eMTB**		**MTB vs eMTB (h:mm:ss)**	**MTB vs eMTB (%)**
	t (h:mm:ss)	**t (%)**	**t (h:mm:ss)**	**t (%)**		
Zone 5 | Maximum > 161	0	0	0	0	0	0
Zone 4 | Thershold 154-160	0:01:27	4,2	0	0	0:01:27	0
Zone 3 | Aerobic 144-153	0:03:12	9,3	0:00:38	2,4	0:02:34	+82,8
Zone 2 | Easy 130-143	0:04:37	14,5	0:02:38	9,9	0:02:19	+43,0
Zone 1 | Warm Up 104-129	0:22:48	66,6	0:17:30	65.7	0:05:18	+23,2
Zone 0 | Below<104	0:01:50	5,4	0:05:51	22,0	-0:04:01	-74,36
Total	0:34:14	100,0	0:26:37	100,0	0:07:37	+22.2

When going downhill on the MTB bicycle, taking 22.2% longer than the eMTB, the largest percentage differences between residence times in the various effort zones occurred in effort zone 3, where the respondent riding the MTB bicycle was 82.5% longer than riding the eMTB bicycle. Riding the MBT bike also had longer residence times in effort zone 3 (by 43.0%) and 1 (by 23.2%). It is worth noting that there was no dwell time at all in effort zone 5, and only 1 min 27 sec in effort zone 4 while riding the MTB bicycle.
In the MTB bicycle descent, lasting 34 min and 14 sec, the subject spent the longest time in effort zone 1 (66.6% of the total descent time). This was followed by effort zone 2 - 14.5% of the total downhill time, and effort zone 3 - 9.3% of the total downhill time. For a smaller period of time, the respondent stayed in effort zone 4 - 4.2% of the total ascent time, and did not stay in effort zone 5 at all.

On the eMTB bicycle descent, lasting 26 mim and 37 sec, the subject primarily stayed in effort zone 1 (65.7%), and effort zone 0 (22.0%). He spent a total of 12.3% of his total descent time in effort zones 2,3, and did not spend any time at all during the descent in effort zones 5 and 4. The MTB bike descent was 7 min and 37 sec longer than the eMTB bike descent.

Analyzing the differences in residence time in the different effort zones, it was noted that the respondent riding an MTB bicycle by far stayed the longest in effort zone 1. The same was true when analyzing downhill with an eMTB bicycle. In the other effort zones riding an MTB bicycle, the residence time decreased from 14.5% in effort zone 2 to 0% in effort zone 5. In the case of downhill riding an eMTB bicycle, the residence time in the study zones was even shorter - from 9.9% in effort zone 2 to 0% in effort zones 4,5.

4. Differences in BMT and eBMT mountain biking with effort zones measured by heart rate (HR) contractions - minor climbs and descents

Differences occurring on a section of small ascents and descents on a MTB and eMTB mountain biking route, taking into account the effort zones measured by heart rate (HR) contractions, are shown in Table 7.

Table 7. Zones of effort and their differences occurring during small climbs and descents on a mountain trail by MTB and eMTB bicycle

Zones of effort -. 2-nd climb&down	**MTB**		**eMTB**		**MTB vs eMTB (h:mm:ss)**	**MTB vs eMTB (%)**
	t (h:mm:ss)	**t (%)**	**t (h:mm:ss)**	**t (%)**		
Zone 5 | Maximum > 161	0:00:22	2,5	0	0	0:00:22	0
Zone 4 | Thershold 154-160	0:03:28	23,5	0	0	0:03:28	0
Zone 3 | Aerobic 144-153	0:03:30	23,6	0	0	0:03:30	0
Zone 2 | Easy 130-143	0:01:02	7,0	0:03:35	36,1	-0:02:30	-71,2
Zone 1 | Warm Up 104-129	0:06:20	42,8	0:04:01	40,4	0:02:19	+36,6
Zone 0 | Below<104 ?	0:00:06	0,7	0:02:20	23,5	-0:02:14	-95,7
Total	0:14:48	100,0	0:09:56	100,0	0:04:52	+32,8

During **minor climbs and descents,** the respondent riding **the MTB bicycle** stayed 32.8% longer than the eMTB. The dominant effort zone was 1, where the MTB rider stayed 36.6% longer than the eMTB rider. It is worth noting that when riding the eMTB bicycle, the respondent did not stay in effort zones 5,4,3 at all, and (by 71.2%) longer in effort zones 2 and 0 (by 95.7%). In contrast, the respondent spent the longest time in effort zone 2 when riding the MTB bike, where he stayed 36.6% longer than when riding the eMTB bike.

For small MTB bike climbs and descents, lasting 14 min and 48 sec, the study participant spent the longest time in effort zone 1 (42.8% of the total time of small climbs and descents). This was followed by effort zones 3 (23.6%) and 4 (23.5% of the total time of small climbs and descents). For a shorter period of time, the respondent was in effort zone 2 - 7.0% of all time of minor ascents and descents and even shorter in effort zone 5 (2.5% of all time of minor ascents and descents).

For minor ascents **and descents with the eMTB bicycle**, lasting 09 mim and 37 sec, the respondent primarily stayed in effort zones 1 and 2 (a total of 76.5% of the total time of minor ascents and descents) and in effort zone 0 (23.5%). There was no stay in effort zone 5,4,3. The passage of minor ascents and descents on the MTB bike was 4 min and 52 sec longer than on the eMTB bike.

The differences in residence times in each zone on a section of small ascents and descents riding an MTB and eMTB bicycle were small, ranging between 2 min and 14 sec. in effort zone 0 to 3 min 30 sec. in effort zone 3.

During minor climbs and descents, the respondent riding the MTB bicycle stayed 32.8% longer than the eMTB. The dominant effort zone was 1, where the MTB rider stayed 36.6% longer than the eMTB rider. It is worth noting that when riding the eMTB bicycle, the respondent did not stay in effort zones 5,4,3 at all, and (by 71.2%) longer in effort zones 2 and 0 (by 95.7%). In contrast, the respondent spent the longest time in effort zone 2 when riding the MTB bike, where he stayed 36.6% longer than when riding the eMTB bike.

5. Differences in BMT and eBMT mountain biking with effort zones measured by heart rate (HR) contractions - total activity

Differences occurring over the entire mountain route in MTB and eMTB cycling with effort zones measured by heart rate (HR) contractions are shown in Table 8.

Table 8. Effort zones and their differences found throughout the mountain route in MTB and eMTB cycling

Zones of effort -. Entire activity	**MTB**		**eMTB**		**MTB vs eMTB (h:mm:ss)**	**MTB vs eMTB (%)**
	t (h:mm:ss)	**t (%)**	**t (h:mm:ss)**	**t (%)**		
Zone 5| Maximum > 161	0:18:51	14,2	0:01:06	2,2	0:17:45	+95,8
Zone 4| Thershold 154-160	0:20:49	15,7	0:06:48	7,9	0:14:01	+67,3
Zone 3| Aerobic 144-153	0:30:43	23,2	0:05:10	6,0	0:25:33	+83,2
Zone 2| Easy 130-143	0:17:59	13,6	0:18:37	21,7	-0:00:38	-3,4
Zone 1| Warm Up 104-129	0:41:42	31,5	0:43:35	40,4	-0:02:13	-4,3
Zone 0 | Below<104 ?	0:02:23	1,8	0:10:09	4,0	-0:07:46	-76,5
Total	2:12:27	100,0	1:25:45	100,0	0:46:42	+35,7

On the entire mountain route in the MTB bike ride, lasting 2 hours, 12 minutes and 27 seconds, the respondent spent the longest time in effort zone 1 (31.5% of the total ride time). This was followed by effort zone 3, with 23.2% of the total climbing time. In zones 5, 4,and 3, the length of stay was similar, ranging between 13.6% and 15.7%. The shortest dwell time occurred in effort zone 0 - 1.8%.

In riding the entire eMTB bicycle route of 1 hour, 25 minutes and 45 seconds, the respondent primarily stayed in effort zone 1 (40.4%), and effort zone 2 (21.7%). He spent between 2.2% and 7.9% of the total ride time in the remaining effort zones 3,4,5 and 0. Traveling the entire route on the MTB bike was 46 minutes and 42 seconds longer than on the eMTB bike.

Analyzing the differences in residence time in the different effort zones, it was noted that the respondent riding the MTB bike definitely stayed longer in effort zones 3,5,4, while riding the eMTB bike in the other effort zones, namely 0, 1 and 2.

When cycling the entire mountain route with an MTB bicycle taking 25.7% longer than an eMTB, the longest effort zone was 1, and the difference in time between rides was only 4.3%.

The largest percentage differences between dwell times in individual effort zones along the entire route occurred in zone 5, where the respondent riding the MTB bike was 95.8% longer than riding the eMTB bike. Riding the MBT bike, the respondent also stayed longer in effort zone 3 (by 83.3%) and effort zone 4 (by 67.3%). It should also be noted that the respondent riding the MTB bicycle was 76.5% shorter in effort zone 0.

Discussion

Mountain bicycle tourism is one form of physical activity that takes into account terrain, physical activity and being in the natural environment (Niezgoda 2012, Meyer 2015, Dąbrowska et al. 2018). The advantage of mountain bicycle tourism, in addition to communing with nature, interpersonal contacts, is the possibility of shaping motor skills and physical fitness away from automobile roads, with nearly four times the speed of travel than on foot (Beim 2012). Mountain biking is classified as an aerobic physical activity, designed for people who have relatively high motor skills, good fitness and fitness preparation.

Special unicycles, called MTB (Mountain Terrain Bike), usually of the hardtail type, are used for mountain biking. They are characterized by wide tires, specific design of frame, saddle, gears, derailleurs, disc brakes or suspension (http://www.ppc.webserwer.pl, https://pl.wikipedia.org/wiki/Hardt, Wiesner et al. 2016). An alternative to classic MTB mountain bikes are unicycles with electric motors called eMTBs. With power assistance, they provide more opportunities for mountain biking, making them an attractive and acceptable tool for increasing activity levels in the mountains (Chaney et al. 2019).

The largest body of scientific research in MTB and eMTB mountain biking has been related to the quality and variability of effort, which was lower in eMTB riders (Simons et al. 2009, Gojanovic et al. 2011), but high enough to reach standards of health-promoting moderate-intensity physical activity (Simons et al. 2009, Louis et al. 2012). Consequently, heart rate and oxygen consumption were also lower during the ride (Berntsen et al. 2017). The ability to stimulate with exercise has been shown to improve metabolism, including glucose regulation (Sperlich et al. 2012, Peterman et al. 2016), which promotes better well-being (Sperlich et al. 2012). The results have also argued for the potential of eMTBs to be used by broader populations, as they can be ridden without excessive fatigue over longer and more varied distances (Gojanovic et al. 2011, Hoj et al. 2018), even with lower physical fitness and lower motor skills or mobility limitations (Blumenstein et al. 2014, Twisk et al. 2017). The above results were verified by our own research, analyzing the route ridden, by the same subject on an MTB and eMTB bicycle. The differences studied were the pace of the ride and exercise, as measured by heart rate (HR). The MTB bicycle's ride time was 45.3% longer, resulting in a slower pace, especially on the ascent and on small climbs and descents, reaching 34%. Despite such differences in pace, there was no significant advantage of the eMTB ride in terms of achieving maximum speeds, which were similar in both rides. The level of effort, as measured by mean heart rate (HR), was also similar, although slightly lower in the eMTB ride (from 8.3% to 14.1%). The differences were even smaller in terms of maximum $HR_{MAX,}$ where the average difference over the entire route was 3.4%.

The mountain biking route is characterized by climbs, descents and sections with a series of light ascents and descents, so studies were made on the achieved pace of the ride and physical exertion as measured by heart rate (HR) in these zones. Heart rate (HR) was indicative of the amount of physical exertion, which was divided into 5 zones and zone 0 (https://running.trigar.pl).

During the MTB bicycle **climb**, taking 70.6%% longer than the eMTB, the largest percentage differences between residence times by zone occurred in effort zone 5, where the respondent riding the MTB bicycle was 94.0% larger than riding the eMTB bicycle. Riding the MTB bicycle also had longer residence times in effort zone 3 (by 81.1%) and effort zone 4 (by 56.2%), and shorter residence times of 43.9.1% in effort zone 1.

When **going downhill on** the MTB bicycle, taking 22.2% longer than the eMTB, the largest percentage differences between residence times in each zone occurred in effort zone 3, where the respondent riding the MTB bicycle was 82.5% longer than riding the eMTB bicycle. Riding the MBT bike also had longer dwell times in effort zone 3 (by 43.0%) and 1 (by 23.2%). It is worth noting that staying in effort zone 5 did not occur at all in both trials, and only for 1 min 27 sec in effort zone 4 when riding the MTB bicycle.

During **small climbs and descents** with the MTB bicycle taking 32.8% longer than the eMTB, the dominant effort zone was 1, where the MTB rider stayed 36.6% longer than with the eMTB bicycle. It is noteworthy that when riding an eMTB bicycle, the respondent did not stay in effort zones 5,4,3 at all, and (by 71.2%) stayed longer in effort zones 2 and 0 (by 95.7%). When riding the MTB bike, on the other hand, the respondent stayed in effort zone 2 the longest, by 36.6% longer than when riding the eMTB bike.

Analyzing the **entire route, it was** found that the MTB bicycle ride took 25.7% longer than the eMTB, and the longest time the subject spent in effort zone 1, where the difference for both rides was only 4.3%. The largest percentage differences were in effort zone 5, where the respondent riding the MTB bike was 95.8% longer than riding the eMTB bike. Riding the MBT bike, the respondent was also longer in effort zone 3 (by 83.3%) and effort zone 4 (by 67.3%). It should also be noted that when riding the MTB bicycle, the respondent was 76.5% shorter in effort zone 0.

Conclusions

1. Covering a mountain biking route is conditioned by your needs and physical capabilities, but with an eMTB bike, you can make more of a decision about the time, pace, level of effort, especially on climbs.
2. The greatest level of exertion, occurring on uphill climbs, can be greatly reduced and adapted to one's own capabilities, while maintaining an appropriate pace by using an eMTB bike.

3. Knowing the differences between MTB and eMTB bicycle use in terms of cycling pace and levels of exertion on a mountain biking route, taking into account one's own psychophysical capabilities and expectations, can lead future adepts of this form of activity to choose the right equipment for them.
4. The ability to choose an MTB or eMTB bike for mountain biking creates the conditions for the participant to be more comfortable riding, controlling the pace and time of the ride, while being able to plan the length of the route and the degree of difficulty.

References:

Bartoszewicz R. (2011) *Motor activity of junior high school students from southwestern Poland against the background of selected European centers*. Wrocław: AWF.

Beim M. (2012) *Bicycle infrastructure and opportunities for its development*, [in:] S. Bródka, P. Zmyślony (eds.). *Tourism in the Poznań agglomeration*, Library of Poznań Agglomeration, No. 20, Bogucki Wyd. Naukowe, Poznań: 158-176.

Berntsen S., Malnes L., Langåker A., Bere E. (2017) *Physical activity when riding an electric assisted bicycle*. Int J Behav Nutr Phys Act 14:55. https://doi.org/10.1186/s12966-017-0513-z.

Blumenstein T., Zeitlmann H., Alves-Pinto A. et al. (2014) *Optimization of electric bicycles for youths with disabilities.* SpringerPlus 3:646. https://doi.org/10.1186/2193-1801-3-646.

Borawska-Melnyk A. (2016) *Can bicycle tourism become a national tourism product in Poland?* http://rowerowypoznan.pl/czy-turystyka-rowerowa-mozestac-sie-narodowym-produktem-turystycznym-w-polsce/ [23.02.2016]

Chaney RA., Cougar Hall P., Crowder AR., Crookston BT., West JH. (2019) *Mountain biker attitudes and perceptions of eMTBs (electricmountain -bikes).* Sport Sciences for Health 2019. https://doi.org/10.1007/s11332-019-00555-z.

Dębowska-Mróz M., Ferensztain-Galardos E., Krajewska R., Rogowski A. (2018) *Bicycle tourism as a form of active tourism on the example of the municipality of the city of Radom*. I Biuletyn KPZK PAN, Komitet Przestrzennego Zagospodarowania Kraju Polskiej Akademii Nauk, Zeszyt 269, pp. 103-128

Feng Z., Raghuwanshi RP., Xu Z. et al. (2010) *Electric-bicyclerelated injury: a rising trafc injury burden in China*. Inj Prev 16:417-419. https://doi.org/10.1136/ip.2009.024646

Gojanovic B., Welker J., Iglesias K. et al. (2011) *Electric bicycles as a new active transportation modality to promote health.* Med Sci Sports Exerc. 43:2204-2210. https://doi.org/10.1249/MSS.0b013 e31821cbdc8.

Hoj T.H., Bramwell J.J., Lister C., et al. (2018) *Increasing active transportation through e-bike use: a pilot study comparing the health benefts, attitudes, and beliefs surrounding e-bikes and conventional bikes*. JMIR Public Health Surv. https://doi. org/10.2196/10461.

International Mountain Bicycling Association (2015) *Electric mountain bicycle regulations for natural surface trails.* Available from https://b.3cdn.net/bikes/ d4d3792f3643272682_2nm6b4ec8 . pdf . Accessed 22 Jan 2019

International Mountain Bicycling Association (2015) *A comparison of environmental impacts from mountain bicycles, Class 1 electric mountain bikes, and motorcycles: soil displacement and erosion on bike-optimized trails in western Oregon forest.* Available from https://b.3cdn.net/bikes/c3fe8a28f1a0f32317_ g3m6bdt7g.pdf. Accessed 22 Jan 2019

Jackowski M., Jaruzalski P. (2012) *The richness of bicycle routes a complete tourism product.* Zeszyty Naukowe Uniwersytetu Szczecińskiego, 701, Ekonomiczne Problemy Usług, 86, 83-94.

Kamińska W., Wilk-Grzywna M. (eds.) (2015) *Uwarunkowania rozwoju turystyki aktywnej na obszarach wiejskich*. Studia KPZK PAN, vol. CLXVI, Warsaw: 5-9.

Kłos-Adamkiewicz Z. (2015) *Bike_S in the eyes of its users,* WZIEU, Szczecin (electronic version).

Kolodziejczyk A., Kalewicz A. (2015) *Determinants of bicycle tourism development in rural areas. Experience of the Wielkopolska voivodeship*, [in:] W. Kamińska, K. Heffner (eds.). *Rural areas - multifunctionality, migration, new visions of development*, Studia KPZK PAN, vol. CXXXIII, Warsaw: 102.

Kozak A. (2019) *The state of and prospects for the development of cycling tourism in Central Roztocze, according to tourists.* The state of and prospects for the development of cycling tourism in Central Roztocze in the Opinion of Tourists. Economic and Regional Studies Economic and Regional Studies, ISSN 2083-3725 Volume 12, No. 4.

Langford B.C., Chen J., Cherry C.R. (2015) *Risky riding: naturalistic methods comparing safety behavior from conventional bicycle riders and electric bike riders.* Accid Anal Prev 82:220-226. https ://doi.org/10.1016/j.aap.2015.05.016.

Louis J., Brisswalter J., Morio C. et al. (2012) *The Electrically Assisted bicycle: an alternative way to promote physical activity.* Am J Phys Med Rehabil 91:931-940. https://doi.org/10.1097/ PHM.0b013e318269d9bb.

MacArthur J., Dill J., Person M. (2014) *Electric bikes in North America*. Transp Res Rec. 2468:123-130. https://doi. org/10.3141/2468-14.

Meyer B. (ed.). (2015) *Serving participants in tourism and recreation.* Difin Publishing House, Warsaw.

Meyer B., Sawinska A. (2018) *Directions of development of bicycle routes in the West Pomeranian Voivodeship*. Proceedings of the Committee on Geography of Communication of the Polish Geographical Society, 21(1), 34-42.

Niezgoda A. (2012) *Market determinants of bicycle tourism development* [in:] J. Śledzińska, B. Włodarczyk (eds.), *Turystyka rowerowa w Zjednoczonej Europie*, PTTK "Kraj" Publishing House, Warsaw, 29-39.

Peterman J.E., Morris K.L., Kram R., Byrnes W.C. (2016) *Pedelecs as a physically active transportation mode*. Eur J Appl Physiol 116:1565-1573. https://doi.org/10.1007/s00421-016-3408-9.

Pieniążek M., Koproń J., Bornikowska A. (2016) *Bicycles as a means of transportation realization and a form of recreation in the Lublin area.* Bus. 12/2016 s. 365- 370.

Pisarska B., Pisarski Z. (2012) *Aspects of development of bicycle tourism in protected areas in Poland* [in:] J. Śledzińska, B. Włodarczyk (eds.) *Turystyka rowerowa w Zjednoczonej Europie,* PTTK "Kraj" Publishing House, Warsaw, 83-97.

Simons M., Van Es E., Hendriksen I. (2009) *Electrically assisted cycling: a new mode for meeting physical activity guidelines?* Med Sci Sports Exerc 41:2097-2102. https://doi.org/10.1249/ MSS.0b013e3181a6aaa4.

Smolarski, T. (2015). *Social determinants of bicycle recreation of high school students.* Doctoral dissertation, typescript. Wrocław: AWF.

Sperlich B., Zinner C., Hébert-Losier K. et al (2012) *Biomechanical, cardiorespiratory, metabolic and perceived responses to electrically assisted cycling.* Eur J Appl Physiol 112:4015-4025. https ://doi.org/10.1007/s00421-012-2382-0.

Twisk D.A.M., Platteel S., Lovegrove G.R. (2017) *An experiment on rider stability while mounting: comparing middle-aged and elderly cyclists on pedelecs and conventional bicycles.* Accid Anal Prev 105:109-116. https://doi.org/10.1016/j.aap.2017.01.004.

Zatoń, K., Zatoń, K. (2014) Physical activity and health. Rozprawy Naukowe AWF Wrocław, 45, 34-40.

Board of the Western *Pomeranian* Voivodship (2016) *Concept of the Western Pomeranian Bicycle Route Network*, Szczecin, p. 29, http://rbgp.pl/userfiles/Koncepcja_raport_aktualizacja_18-04-2016.pdf.

WHO (2021) *Guidelines on physical activity and sedentary behavior: at a glance.* C:/Users/Dell/Downloads/WHO-EURO-2021-1204-40953-58211-pol%20(1).pdf).

Wiesner W. (2011) *Risk management and education for safety in recreation.* Zeszyty Naukowe WSB w Wrocławiu, 23, 197-210.

Wiesner W., Smolarski T., Szwej P. (2016) *Characteristics of cyclists practicing bicycle tourism in the Jizera Mountains.* Rozprawy Naukowe Akademii Wychowania Fizycznego we Wrocławiu 56, pp. 51-58.

Netography

http://www.aktivtour.pl/jakjazda-rowerem-wplywa-na-zdrowie, accessed 15.04.2023

http://www.zdrowy-rower.pl/ safe-tourism-cycling-in-poland. Accessed: 20.04.2023.

https://www.centrumrowerowe.pl/blog/przeciwwskazania-do-jazdy-na-rowerze/Data updates: 21-04-2020, accessed:17/04/2023.

https://portal.abczdrowie.pl/jazda-na-rowerze-efekty-wskazania-i-przeciwwskazania, accessed 10.04.2023.

https://www.siroko.com/blog/c/pl/negatywny-wplyw-jazdy-na-rowerze-na-nasz-organizm/, accessed April 10, 2023.

https://beskidyrowerem.eu/gorskie-trasy-rowerowe-mtb-w-beskidzie/)

(http://www.ppc.webserwer.pl), accessed 07.04.2023.

(https://pl.wikipedia.org/wiki/Hardt, accessed 13.04.2023.

/strefa-tetna-pulsometers-garmin/https://running.trigar.pl, accessed 06.04.2023.

https://www8.garmin.com/manuals/webhelp/fenix6-6ssport/PL-PL/GUID-1FBCCD9E-19E1-4E4C-BD60-1793B5B97EB3.html , accessed. 11.04.2023.