COMMISSION FOR THE EVALUATION OF A DOCTORAL DISSERTATION

TO THE TEACHING AND SCIENTIFIC COUNCIL OF THE FACULTY OF SPORT AND PHYSICAL EDUCATION

Subject: Report on the review and evaluation of the doctoral dissertation of Ljubica Ristanović (student ID number: 5006/2019), a student from the doctoral academic studies program.

The Teaching and Scientific Council of the University of Belgrade – Faculty of Sport and Physical Education, at its 11th session held on April 4, 2024, in accordance with Article 40 of the Regulations on Doctoral Academic Studies – *consolidated text* (02-no. 532/22-4 dated November 9, 2022) and Articles 41–43 of the Statute of the University of Belgrade – Faculty of Sport and Physical Education – *consolidated text* (02-br. 188/23-2 dated February 13, 2023), based on the proposal of the Council of Doctoral Academic Studies (02-no. 81/23-10 dated November 30, 2023), decided to form the Commission for the evaluation of the doctoral dissertation of Ljubica Ristanović, titled: **"Pacing strategy in half-marathon and marathon based on performance level, sex and age (Strategija tempa trčanja polumaratona i maratona u zavisnosti od takmičarske uspešnosti, pola i starosti)"**. The Commission is composed of:

1. Associate professor Milan Matić, PhD, University of Belgrade – Faculty of Sport and Physical Education, Belgrade, Serbia, commission president;
2. Associate professor Igor Ranisavljev, PhD, University of Belgrade – Faculty of Sport and Physical Education, Belgrade, Serbia, member;
3. Associate professor Vladimir Mrdaković, PhD, University of Belgrade – Faculty of Sport and Physical Education, Belgrade, Serbia, member;
4. Associate professor Miloš Marković, PhD, University of Belgrade – Faculty of Sport and Physical Education, Belgrade, Serbia, member;
5. Full professor Beat Knechtle, PhD, Institute of Primary Care, University of Zurich, Zurich, Switzerland, member.

The doctoral dissertation was completed under the supervision of:

1. Full professor Stanimir Stojiljković, PhD, University of Belgrade – Faculty of Sport and Physical Education, Belgrade, Serbia;
2. Assistant professor Ivan Ćuk, PhD, University of Belgrade – Faculty of Sport and Physical Education, Belgrade, Serbia.

After reviewing the submitted materials, the Commission shall submit the following to the Teaching and Scientific Council:

REPORT:

Candidat Ljubica Ristanović has submitted the final version of her doctoral dissertation entitled: "**Pacing strategy in half-marathon and marathon based on performance level, sex and age (Strategija tempa trčanja polumaratona i maratona u zavisnosti od takmičarske uspešnosti, pola i starosti)**" to the Faculty archives on March 28, 2024. The doctoral dissertation includes 114 pages, 15 tables, 23 figures, 3 pictures, and a list of 264 references cited within the work. The doctoral dissertation was completed in full compliance with the Regulations on Doctoral Studies of the Faculty of Sports and Physical Education and with the Instructions on the Formation of the Repository of Doctoral Dissertations adopted by the Senate of the University of Belgrade. The dissertation is written in English language and contains: a front page in English and Serbian language, a list of PhD supervisors and committee members, expressions of gratitude in English and Serbian language, abstract in English and Serbian language, list of abbreviations, content, and then chapters: Introduction; Previous research; Research problem, subject, aims and tasks; Research hypotheses; Methods; Results; Discussion; Limitations of the study and future research; Potential significance and practical application of the research; Conclusions; References and additional documents mentioned at the end of this report.

Biography of the candidate

Ristanović (Dušan) Ljubica, born on September 8, 1995, in Smederevo, Republic of Serbia, completed Živomir Savković elementary school in Kovačevac as the "highest achieving pupil". She graduated from the Mladenovac Gymnasium in 2014. She obtained her Bachelor’s degree at the University of Belgrade, Faculty of Sport and Physical Education in the academic year 2017/18, earning the honors of "highest achieving undergraduate student". Subsequently, she completed her Master's studies in the academic year 2018/19 and enrolled in the Doctoral studies program at the same school. Additionally, alongside these studies, she completed her Master's studies at the University of Belgrade, Faculty of Medicine, in the academic year 2020/21. During her Master's studies, she had the opportunity to enhance her professional development by participating in the ERASMUS+ project. As part of this project, she spent one semester at the University of Sports Science in Rome, "Foro Italico". As part of her Doctoral studies, she furthered her professional development through the same project, spending one semester at the University of Granada, Faculty of Sport Sciences, in the academic year 2022/23. During her Bachelor studies in 2016, she spent four months in Alaska, USA, through the "Work and Travel" program for students. She trained in karate for 10 years with the Mladenovac Karate Club and attained the rank of "Master of Karate" with a 1st Dan Black Belt in 2011. She also earned national and international medals for her achievements in the sport. Since then, she has been engaging in recreational running, and for the past five years, also in triathlon. Currently, she is employed temporarily as teaching assistant at the Faculty of Sport and Physical Education Department of Sports and Recreation Theory and Methodology. She has been involved in teaching as an associate (demonstrator) since the academic year 2018/19. Since March 2023, she has been working as a coach at the BRAVEHEARTS recreational club. Her most extensive practical experience was gained at the Belgrade Running Club, where she worked as a coach for recreational runners for six years. Since 2017, she has been actively involved in providing individual training sessions to recreational athletes in the field of fitness.

Published research

Ristanović, L., Cuk, I., Villiger, E., Stojiljković, S., Nikolaidis, P.T., Weiss, K., Knechtle, B. (2023). The pacing differences in performance levels of marathon and half-marathon runners. *Frontiers in Psychology,* 14:1273451. doi: 10.3389/fpsyg.2023.1273451

Structure of the Doctoral Dissertation

In the **introduction**, the author states that long-distance running has gained global popularity in the past 50 years (Knechtle et al., 2018; Vitti et al., 2020). Despite more older runners joining, overall performance has declined due to the increasing number of participants (Knechtle et al., 2018; Stojiljković et al., 2019, 2022; Vitti et al., 2020), suggesting a rise in recreational runners (Stojiljković et al., 2021). However, the top 10 finishers have shown improvement (Knechtle et al., 2018). Based on the race results from around the world, it was mentioned that recreational runners take several times longer to complete races compared to elite athletes. It was concluded from this observation, that running the same distance does not entail the same level of exertion for athletes and recreational runners (Monte et al., 2020).

It is stated that running long distances has an impact on endurance and various positive physiological effects (Davies, 2018; Papić et al., 2019) and improves overall health (Virnitzer et al., 2022), reducing the risk of cardiovascular and malignant diseases (Pedisić et al., 2020). However, excessive doses of running training do not necessarily have a favorable association with mortality (Pedisic et al., 2020) and health (Toresdahl et al., 2021, 2023). It can also increase the risk of running-related injuries (Damsted et al., 2018; Gomes Neto et al., 2023) which are more common in less experienced (Damsted et al., 2019; Papić et al., 2021) and slower runners (Damsted et al., 2019). The risk of developing diseases due to high absolute training loads is higher in recreational and lower-ranked athletes (Shephard & Shek, 2015) compared to elite athletes (Malm, 2006). Therefore, it is important to maintain the upward trend of mass participation in long-distance running events while ensuring proper guidance and dosage of the training process.

The author classifies the factors influencing long-distance running performance into external and internal. External factors include the course profile, course quality, external conditions (altitude, temperature and humidity, wind speed), nutrition and hydration before and during the race, warm-up, pacing strategy (PS), etc. When it comes to the internal factors, the author mentions the integration of muscular, cardiovascular, and neurological factors that function cooperatively (Joiner & Coile, 2008). Of the aforementioned performance factors, many studies indicate that PS is one of the key factors for success in long-distance races (Foster et al., 2023; Kais et al., 2019; Skorski & Abbiss, 2017; Smyth, 2018; Venturini & Giallauria, 2022).

In the subchapter **"Concept and Significance of Pacing Strategy in Long-Distance Running"** it is mentioned that some definitions indicate that pacing strategy refers to the distribution of energy reserves, power, and speed throughout the race without significant deceleration (Baron et al., 2011; Tucker & Noakes, 2009). It can be said that the decision on a current pace in a race is an integration of anticipation, knowledge of the finish line, previous experience, and sensory feedback received by the runner (Foster et al., 2023; Skorski & Abbiss, 2017; St Clair Gibson et al., 2006). The most important factor in choosing a running pace is the race distance or duration (St Gibson et al., 2006). Factors that significantly influence PS include the depletion of glycogen stores, thermoregulation, neuromuscular fatigue, and an increased rating of perceived exertion (RPE) (Foster et al., 2023). The optimal PS plays a crucial role in preventing intolerable homeostatic disturbances during a race (Foster et al., 2023; Koning et al., 2011; Tucker & Noakes, 2009), reduces the risk of musculoskeletal injuries (Koning et al., 2011), and makes the race more enjoyable for recreational runners (Cuk, Nikolaidis, & Knechtle, 2019).

In the subchapter **"Types of Pacing Strategies in Long-Distance Running",** the author mentions the most common PSs during long-distance races: even (Koning et al., 2011; Pryor et al., 2020), positive, negative (Koning et al., 2011; Pryor et al., 2020), variable (ibid.), terrain-dependent (Pryor et al., 2020), reverse J-shaped parabolic (Abbiss & Laursen, 2008; INEOS 1:59 Challenge, 2023; Nikolaidis & Knechtle, 2018a, 2018b), and U-shaped parabolic pacing (Abbiss & Laursen, 2008; Casado et al., 2021). It was suggested that sustaining an even pace is the most efficient metabolic strategy for completing long-distance races in any given situation (Rapoport, 2010). Some studies suggest that negative PS may be most appropriate for long-duration activities such as marathons, as it is associated with decreased carbohydrate utilization, lower oxygen consumption, and lower blood lactate concentrations (Abbiss & Laursen, 2008; Hanley, 2014).

The chapter **"Previous Research"** presented PSs based on performance levels and/or sex and/or age in road race disciplines with the highest popularity (5 km, 10 km, half-marathon and marathon races) (Hernando et al., 2020; Kais et al., 2019; Muñoz-Pérez et al., 2020; Pycke & Billat, 2022; Hanley, 2014b; De Leeuw et al., 2018; Lima-Silva et al., 2010; Casado et al., 2021). The PS of the world's top marathon runners has changed over the last 50 years (Díaz et al., 2018). Athletes began races faster than the world record pace between 1967 and 1988 but slowed down significantly in the final kilometers while since 1988, the pace has shifted from positive to negative (ibid).

In the subchapter **"Running Pacing Strategy based on Performance Level",** the PS in the disciplines of 5 km, 10 km, half-marathon, and marathon are analyzed based on previous research. Limited data on PSs have been presented for 5 km and 10 km races, likely due to the difficulty of recording split times, which are typically divided into 5 km segments in races with a large number of participants. In half-marathon, slightly negative and positive PSs were observed in high-performance runners (De Leeuw et al., 2018) and a parabolic reverse J-shaped ST among elite runners (Hanley, 2014b), but the evidences are also limited. Marathon running is typically associated with positive pacing (De Leeuw et al., 2018; Kais et al., 2019; Stojiljković et al., 2020). Runners with higher performance levels exhibited a more evenly distributed PS compared to runners with lower performance levels (Chatzakis et al., 2021; Kais et al., 2019; Nikolaidis & Knechtle, 2017; Santos-Lozano et al., 2014). It can be observed that elite marathoners maintain an even running pace (Muñoz-Pérez et al., 2020).

The subchapter **"Running Pacing Strategy based on Sex"** presents the PSs in 10 km, half-marathon, and marathon races based on sex. Limited data were presented in the 10 km race, only on the athletics track among elite runners (Borba et al., 2021). The author notes that there was only one study that compared the PS in the half-marathon between elite women and men (Stanković et al., 2019). In the study, among the top 50 male finishers, a significant pace decline was observed after the first 5 km, while the top 50 female finishers had more evenly distributed PS. However, a decline in pace was observed in both sexes as the race progressed. Previous research has identified significant differences in marathon running PS between men and women (Kais et al., 2019; Stojiljković et al., 2020) and there are also studies where no differences in running PS between men and women were found (Trubee et al., 2014). Positive running PS has been observed in both sexes regardless of performance level (Breen et al., 2018; De Leeuw et al., 2018; Kais et al., 2019), except for world record holders (Díaz et al., 2019). It has been found that women who run marathons recreationally start the race more conservatively, maintain a more even pace throughout the marathon and experience less pace deceleration in the final part of the race (De Leeuw et al., 2018). It can be assumed that men overestimate their abilities at the beginning of the race, leading to significant pace deceleration during the race, and overconfidence can be one of the psychological factors that partially explain poorer running PS in men (Hubble & Zhao, 2016). However, negative running PS (Díaz et al., 2019), and even acceleration towards the end (Muñoz-Pérez et al., 2022), have been observed in men's world record holders in the marathon, while it is less frequently observed in women (Díaz et al., 2019).

In the subchapter **"Running Pacing Strategy based on Age"**, it is stated that only new methodology studies examined PS based on age in 10 km and half-marathon races. Regarding marathon, the largest number of participants is in the age category of 30–39 years old, both in Serbia and abroad (Lepers & Cattagni, 2012; Stojiljković et al., 2019). Previous research indicates significant differences in running PSs between different age groups (Kais et al., 2019; March et al., 2011; Nikolaidis & Knechtle, 2017). Older runners had a more consistent pace compared to younger runners with similar performance levels (Kais et al., 2019; March et al., 2011; Nikolaidis & Knechtle, 2017), and a more pronounced difference was observed between groups with lower performance levels (Nikolaidis & Knechtle, 2017). Some studies, however, indicate trivial differences in running PSs among different age groups (Nikolaidis & Knechtle, 2018a, 2019).

In the subchapter **"Comparison of Running Pacing Strategy between Races of Different Distances",** the importance of comparing running PSs between different long-distance races is highlighted due to a lack of understanding of the mechanism that causes a significant decrease in running speed during the second half of the marathon. The analyzed studies using new methodology have directly compared PS between the half-marathons and marathons held in the same event (Vienna and Ljubljana 2017) and under similar outside conditions (Cuk, Nikolaidis, & Knechtle, 2019; Cuk et al., 2019; Nikolaidis et al., 2019). In both the half-marathon and marathon races, a decrease in running speed during the race was observed for both sexes and across all age categories, with a characteristic end spurt (ES) observed in marathon runners (Nikolaidis et al., 2019). In one study, an ES was recorded in a half-marathon (Cuk et al., 2019), while in other studies it was not observed (Nikolaidis et al., 2019; Nikolaidis, Ćuk, & Knechtle, 2019). Moreover, in both sexes and most age categories, pacing in the half-marathon was found to be more evenly distributed compared to the marathon (Cuk, Nikolaidis, & Knechtle, 2019; Cuk et al., 2019; Nikolaidis et al., 2019; Nikolaidis, Ćuk, & Knechtle, 2019).

In the subchapter **"Conclusions and Limitations of Previous Research",** the following conclusions are listed:

1. The majority of research on long-distance running PS has focused on the marathon discipline, with a large sample size and considering three factors: performance level, sex and age (Kais et al., 2019; Muñoz-Pérez et al., 2020; Nikolaidis & Knechtle, 2018a; Pycke & Billat, 2022; Stojiljković et al., 2020).
2. Only one study has investigated PS in the half-marathon based on performance level, and only among elite athletes, with a small sample size (Hanley, 2015).
3. Only one study has analyzed PS in the half-marathon based on sex, but focusing on elite runners (Stanković et al., 2019).
4. No study to date has examined PS in the half-marathon based on age.
5. Studies that have used new methodologies have compared the half-marathon and marathon disciplines in a single year, with a relatively small sample size, considering sex and/or age (Cuk, Nikolaidis, & Knechtle, 2019; Cuk et al., 2019; Nikolaidis, Ćuk, & Knechtle, 2019). However, none of these studies have compared PS in the half-marathon and marathon based on performance level.

Considering the above, the limitations of previous research are as follows:

1. Insufficient studies, particularly with relatively small sample sizes, have examined PS in the half-marathon, despite being perhaps the most popular race worldwide in terms of the number of races and participants every year (Knechtle et al., 2016; Nikolaidis et al., 2021).
2. Comparisons between half-marathon and marathon PSs have been conducted on relatively small sample sizes, focusing solely on sex and age.
3. No study to date has compared half-marathon and marathon PSs based on performance level.

It is stated that to address these limitations, it would be valuable to conduct research comparing PSs based on performance level, sex, and age in races of different distances held on the same day. This would provide a clearer understanding of the factors that have the greatest impact on long-distance running PS. As a pilot study for this doctoral thesis, data on PS based on performance levels for half-marathon and marathon runners was published under the title "The pacing differences in performance levels of marathon and half-marathon runners".

In the chapter **"Research Problem, Subject, Aims, and Tasks"** it is stated that the research problem is pacing strategy in half-marathon and marathon runners. The subject of the research is the analysis and comparison of pacing strategies in half-marathon and marathon runners, based on performance level, sex and age of runners, in races held under similar external conditions. The research aims and tasks are defined based on the research problem and subject.

Aim 1: Comparison of pacing strategies in half-marathon and marathon runners.

a) Comparison of pacing strategies in half-marathon and marathon runners based on performance level.
b) Comparison of pacing strategies in half-marathon and marathon runners based on sex.
c) Comparison of pacing strategies in half-marathon and marathon runners based on age.

Aim 2: Analysis of pacing strategies in half-marathon runners.

a) Analysis of pacing strategies in half-marathon runners based on performance level.
b) Analysis of pacing strategies in half-marathon runners based on sex.
c) Analysis of pacing strategies in half-marathon runners based on age.

Aim 3: Analysis of pacing strategies in marathon runners.

a) Analysis of pacing strategies in marathon runners based on performance level.
b) Analysis of pacing strategies in marathon runners based on sex.
c) Analysis of pacing strategies in marathon runners based on age.

The research aims will be achieved through the following tasks:

a) Obtaining approval from the Ethics Committee.
b) Collecting publicly available data from the official website of the Vienna Marathon for 17 half-marathon and marathon races (2006–2023 period, except 2020).
c) Cleaning and organizing the collected database.
d) Performing statistical analysis of the data.
e) Interpreting the research findings.

In the chapter **"Research Hypotheses",** hypotheses are defined based on a review of previous research and in line with the research aims.

Hypothesis 1: The pacing of half-marathon runners is more evenly distributed compared to the pacing of marathon runners.

a) The pacing of half-marathon runners is more evenly distributed compared to the pacing of marathon runners in all performance groups of both sexes.

b) Female runners pace more evenly compared to male runners in both races, with differences greater in the marathon than in the half-marathon.

c) Middle-aged runners pace more evenly compared to younger and older runners, with differences greater in the marathon than in the half-marathon.

Hypothesis 2: The pacing strategy of half-marathon runners is positive.

a) Higher-performance-level runners of both sexes, pace more evenly compared to runners of lower performance levels in the half-marathon.

b) Female runners pace more evenly compared to male runners in the half-marathon.

c) Middle-aged runners of both sexes pace more evenly compared to younger and older runners in the half-marathon.

Hypothesis 3: The pacing strategy of marathon runners is positive.

a) Higher-performance-level runners of both sexes, pace more evenly compared to runners of lower performance levels in the marathon.

b) Female runners pace more evenly compared to male runners in the marathon.

c) Middle-aged runners of both sexes pace more evenly compared to younger and older runners in the marathon.

In the **Methods** chapter, under the subheading **"Research Design"** it states that the study is quasi-experimental with an ex-post facto design.

In the subheading **"Sample of Participants",** the author mentions that the sample of participants included all runners who completed the Vienna Half-Marathon and Marathon races from 2006 to 2023 (excluding 2020, when races were not held due to COVID-19), based on official data from the Vienna Marathon organizer's website. Participants with missing data such as sex, age, result in any race segment, final result, and race placement were excluded from the analysis. Additionally, any results in race segments slower than 4.48 km/h, and any CS (Change of Speed) and ACS (Absolute Change of Speed) absolute values of 0% or greater than 50%, were excluded from the analysis. Moreover, in each subcategory for sex, age, and race (total of 24), any "far out" and "extreme out" values identified through SPSS were excluded for logarithmically transformed variables. After the initial data-cleaning process, the final sample comprised 233,083 participants, with 150,232 participants in the half-marathon (men, N = 100,695; women, N = 49,537) and 82,815 participants in the marathon (men, N = 67,118; women, N = 15,697). The sample totaled 167,813 men and 65,234 women.

The subheading **"Race Details"** explains that the Vienna Half-Marathon and Marathon usually take place on the same day each year, which is a Sunday in the second half of April at 9 am. Throughout the entire observed period, both race courses were on an officially certified and fairly flat track with an elevation difference of only 44 meters. The marathon course encompassed the entire route of the half-marathon and remained almost identical throughout the analyzed period of 17 years (2006–2023, except 2020). The information regarding the outside temperatures on race days during the period 2006–2023 was retrieved from the official website (Vienna City Marathon, 2021) and directly from the race organizers of the Vienna City Marathon, by email. Throughout the days of the race in this period, the temperature ranged from 7.8 °C (in 2017) to 21 °C (in 2018) at 9 am, and from 10.8 °C (2012 and 2016) to 25.9 °C (in 2021) at 2 pm.

The subheading **"Data Collection and Processing"** explains the process of data retrieval from the official Vienna Marathon website (Vienna City Marathon, 2023), including exporting the data for each year, discipline and sex into Excel documents. The half-marathon and marathon were divided into 5 segments and constituted the dependent variables of the research. In the half-marathon, the first four segments were 5 km each, and the fifth segment was 1.0975 km, while in the marathon, each segment was twice the length of those in the half-marathon (Cuk, Nikolaidis, & Knechtle, 2019; Nikolaidis et al., 2019; Ristanović et al., 2023). The average running speed for the entire race and for each of the five race segments was calculated for each participant in the half-marathon and marathon (Cuk, Nikolaidis, & Knechtle, 2019; Nikolaidis, Cuk, et al., 2019). The first independent variable was the performance level, with participants divided into four groups (quartiles) based on their performance level (separately for sex, age groups and discipline). The second independent variable was the sex of the participants, i.e., men and women. The third independent variable was six age groups, each spanning 10 years (except for the youngest and the oldest participants groups, which had bigger ranges: 18-29 years and ≥70 years). The fourth independent variable was the type of race: half-marathon and marathon.

In the subchapter **"Statistical Data Analysis"** it is stated that descriptive statistics were followed by an examination of the normality of data distribution using the Kolmogorov-Smirnov and Shapiro-Wilk tests and visual inspection of histograms and Q-Q plots. Since all pacing variables were expressed as percentages, before t-tests and all ANOVAs (analysis of variances) were performed, data were log-transformed for the analyses and then back-transformed according to existing methods (Stewart & Hopkins, 2000). Bonferroni's test was used for all post-hoc comparisons. The effect size was represented by eta-squared (η^2) and described using common guidelines: >0.0099 = small effect, >0.0588 = medium effect, >0.1379 = large effect (Cohen, 1988, 284–288). The alpha level was set at $p < 0.05$. All statistical analyses were conducted using Microsoft Office Excel 2019 (Microsoft Corporation, Redmond, WA, USA) and IBM SPSS Statistics 20 (IBM, Armonk, NY, USA).

In *the Comparison of Pacing Strategies in Half-Marathon and Marathon,* to confirm Hypothesis 1, a mixed between-within subjects ANOVA was conducted to investigate the effect of the race (half-marathon and marathon) on participants' CS in five race segments. Subsequently, an independent-sample t-test was performed to examine the difference in ACS between races. In *the Comparison Based on Performance Level,* to confirm Hypothesis 1a, a two-way between-groups ANOVA was conducted to investigate the effect of performance level and race on ACS (separately for men and women). The same procedure was used to examine the interaction between race and performance level, the main effects of race and the main effects of performance level. In *the Comparison Based on Sex,* to confirm Hypothesis 1b, a two-way between-groups ANOVA was conducted to investigate the effect of sex and race on ACS. The same procedure was used to examine the interaction between race and sex, the main effects of race and the main effects of sex. In *the Comparison Based on Age* category to confirm Hypothesis 1c, a two-way between-groups ANOVA was conducted to investigate the effect of age group and race on ACS (separately for men and women). The same procedure was used to examine the interaction between race and age group, the main effects of race and the main effects of age group.

In *the Analysis of Pacing Strategies in Half-Marathon,* to confirm Hypothesis 2, a repeated measures ANOVA was conducted to examine the difference in average speed between each of the five race segments in the overall sample from the half-marathon. In *the Analysis of Pacing Strategy Based on Performance Level,* to confirm Hypothesis 2a, a mixed between-within subjects ANOVA was conducted to examine the influence of performance level on change of speed in the five race segments (separately for men and women). This statistical analysis was used to assess the interaction between segment CS and performance level, the main effects for segment CS and the main effects for performance level. For a more detailed analysis and confirmation of Hypothesis 2a, a two-way between-groups ANOVA was conducted to examine the influence of performance level and sex on ACS. The same procedure was used to investigate the interaction between sex and performance level, the main effects of sex and the main effects of performance level. In this way we analyzed ACS between male and female runners within each performance group in the half-marathon. In *Analysis of Pacing Strategies Based on Sex,* to confirm Hypothesis 2b, a mixed between-within subjects ANOVA was conducted to examine the influence of sex on change of speed in the five race segments. This statistical analysis was used to assess the interaction between segment CS and sex, the main effects for a segment CS and the main effects for sex. In *the Analysis of Pacing Strategies Based on Age,* to confirm Hypothesis 2c, a mixed between-within subjects ANOVA was conducted to examine the influence of age group on change of speed in the five race segments (separately for men and women). This statistical analysis was used to assess the interaction between segment CS and age group, the main effects for a segment CS and the main effects for an age group. For a more detailed analysis and confirmation of Hypothesis 2c, a two-way between-groups ANOVA was conducted to examine the influence of age group and sex on ACS. The same procedure was used to investigate the interaction between sex and age group, the main effects of sex and the main effects of age group. In this way we analyzed ACS between male and female runners within each age group in the half-marathon.

In *Analysis of Pacing Strategies in Marathon,* to confirm Hypothesis 3 and sub-hypotheses 3a, 3b, and 3c, the exact same statistical analysis was conducted as in the confirmation of Hypothesis 2 and sub-hypotheses 2a, 2b, and 2c.

In the chapter "**Results**", under the subchapter "**Comparison of Pacing Strategies in the Half-Marathon and Marathon**" there was a significant interaction between race and segment CS, Wilks' Λ (Lambda) = 0.96, $F (4, 233042) = 2125$, $p < 0.001$, $\eta^2 = 0.005$. There was a substantial main effect for segment CS, Wilks' $\Lambda = 0.43$, $F (4, 233042) = 75946$, $p < 0.001$, $\eta^2 = 0.154$. The main effect comparing the two races was significant, $F (1, 233045) = 5370$, $p < 0.001$, $\eta^2 = 0.008$. There was a significant difference in ACS for half-marathoners (mean = 4.66±2.62) and marathoners (mean = 5.54±3.84), with $t (130565) = –24.41$ and $p < 0.001$, two-tailed. The magnitude of the differences in the means (mean difference = –0.03, 95% CI: –0.03 to –0.03) was very small ($\eta^2 = 0.003$). Under the subheading *Comparison Based on Performance Level,* regarding only male runners, the interaction effect between performance level and race was significant, $F (3, 167805) = 52.47$, $p < 0.001$, $\eta^2 = 0.001$. There was a significant main effect for performance level, $F (3, 167805) = 11238$, $p < 0.001$, $\eta^2 = 0.16$. The main effect for race was significant, $F (1, 167805) = 1989$, $p < 0.001$, $\eta^2 = 0.010$. Within each performance group, races differed significantly from each other ($p < 0.001$). Regarding only female runners, the interaction effect between performance level and race was significant, $F (3, 65226) = 35.05$, $p < 0.001$, $\eta^2 = 0.001$. There was a significant main effect for performance level, $F (3, 65226) = 4240$, $p < 0.001$, $\eta^2 = 0.161$. The main effect for race was significant, $F (1, 65226) = 1085$, $p < 0.001$, $\eta^2 = 0.014$. In both sexes, all performance groups differ significantly from each other and within each performance group of both sexes, races differed significantly from each other. Under the subheading *Comparison Based on Sex,* the interaction effect between sex and race was significant, $F (1, 233043) = 1847$, $p < 0.001$, $\eta^2 = 0.008$. There was a significant main effect for sex, $F (1, 233043) = 854.7$, $p < 0.001$, $\eta^2 = 0.004$. The main effect for race was also significant, $F (1, 233043) = 5.87$, $p < 0.05$, $\eta^2 = 0.000$. Under the subheading *Comparison Based on Age*, regarding only male runners, the interaction effect between age groups and race was significant, $F (5, 167801) = 36.91$, $p < 0.001$, $\eta^2 = 0.001$. There was a significant main effect for age groups, $F (5, 167801) = 241.7$, $p < 0.001$, $\eta^2 = 0.007$. Also, the main effect for race was significant, $F (1, 167801) = 537$, $p < 0.001$, $\eta^2 = 0.003$. Half-marathoners and marathoners differ from each other significantly in each age group ($p < 0.001$). Regarding only female runners, the interaction effect between age groups and race was significant, $F (5, 65222) = 23.07$, $p < 0.001$, $\eta^2 = 0.002$. There was a significant main effect for age groups, $F (5, 65222) = 81.77$, $p < 0.001$, $\eta^2 = 0.006$. The main effect for race was not significant, $F (1, 65222) = 1.44$, $p = 0.230$.

Under the subchapter "**Analysis of Pacing Strategies in the Half-Marathon**", there was a significant difference between each segment's mean speed, Wilks' $\Lambda = 0.24$, $F (4, 150228) = 121000$, $p < 0.001$, $\eta^2 = 0.350$. All half-marathoners exhibited a decrease in speed up to the fifth segment, followed by an increase in the fifth segment, indicating a noticeable ES. Under the subheading *Analysis of Pacing Strategies Based on Performance Level,* regarding only male half-marathon runners, there was a significant interaction between performance level and segment CS, Wilks' $\Lambda = 0.95$, $F (12, 266395) = 447.9$, $p < 0.001$, $\eta^2 = 0.010$. There was a substantial main effect for segment CS, Wilks' $\Lambda = 0.39$, $F (4, 100688) = 38713$, $p < 0.001$, $\eta^2 = 0.191$. The main effect comparing performance groups was significant, $F (3, 100691) = 7449$, $p < 0.001$, $\eta^2 = 0.052$. Significant differences in all performance groups between each segment CS were found. Regarding only female half-marathon runners, there was a significant interaction between performance level and segment CS, Wilks' $\Lambda = 0.95$, $F (12, 131044) = 220.9$, $p < 0.001$, $\eta^2 = 0.009$. A substantial main effect for segment CS was observed, Wilks' $\Lambda = 0.36$, $F (4, 49530) = 22137$, $p < 0.001$, $\eta^2 = 0.23$. The main effect comparing performance groups was significant, $F (3, 49533) = 3739$, $p < 0.001$, $\eta^2 = 0.047$. Significant differences in almost all performance groups between each segment CS were found. Concerning the ACS variable, the interaction effect between performance level and sex was significant, $F (3, 150224) = 34.88$, $p < 0.001$, $\eta^2 = 0.001$. There was a significant main effect for performance level, $F (3, 150224) = 11171$, $p < 0.001$, $\eta^2 = 0.182$. All performance groups inside of each sex differ significantly from each other. The main effect for sex was significant, $F (1, 150224) = 285.4$, $p < 0.001$, $\eta^2 = 0.002$. In most performance groups male and female participants differ significantly from each other. Under the subheading *Analysis of Pacing Strategies Based on Sex,* there was a significant interaction between sex and segment CS, Wilks' $\Lambda = 1$, $F (4, 150227) = 152.8$, $p < 0.001$, $\eta^2 = 0.001$. A substantial main effect for segment CS, Wilks' $\Lambda = 0.41$, $F (4, 150227) = 53879$, $p < 0.001$, $\eta^2 = 0.187$, was found. The main effect comparing sexes was significant, $F (1, 150230) = 157.2$, $p < 0.001$, $\eta^2 = 0.000$. Significant differences between sexes inside of each segment were observed. Under the subheading *Analysis of Pacing Strategies Based on Age*, regarding only male half-marathon runners, there was a significant interaction between age group and segment CS, Wilks' $\Lambda = 0.98$, $F (20, 333938) = 76.5$, $p < 0.001$, $\eta^2 = 0.003$. There was a substantial main effect for segment CS, Wilks' $\Lambda = 0.8$, $F (4, 100686) = 6426$, $p < 0.001$, $\eta^2 = 0.037$. The main effect comparing age groups was significant, $F (5, 100689) = 132.2$, $p < 0.001$, $\eta^2 = 0.002$. Regarding only female half-marathon runners, there was a significant interaction between age group and segment CS, Wilks' $\Lambda = 0.98$, $F (20, 164266) = 59.86$, $p < 0.001$, $\eta^2 = 0.005$. There was a substantial main effect for segment CS, Wilks' $\Lambda = 0.91$, $F (4, 49528) = 1209$, $p < 0.001$, $\eta^2 = 0.016$. The main effect comparing age groups was significant, $F (5, 49531) = 54.11$, $p < 0.001$, $\eta^2 = 0.002$. In both sexes, significant differences in almost all age groups between each segment CS and between most age groups inside each segment were observed. Concerning the ACS variable, the interaction effect between sex and age group was significant, $F (5, 150220) = 18.38$, $p < 0.001$, $\eta^2 = 0.001$. There was a significant main effect for sex, $F (1, 150220) = 21.09$, $p < 0.001$, $\eta^2 = 0.000$. Significant differences between sexes in most age groups were found. Additionally, the main effect for age group was significant, $F (5, 150220) = 274.4$, $p < 0.001$, $\eta^2 = 0.009$. A significant differences between most age groups among male participants were observed, while less among female participants.

Under the subchapter "**Analysis of Pacing Strategies in the Marathon**", there was a significant difference between each segment's mean speed, Wilks' $\Lambda = 0.37$, $F (4, 82811) = 35382$, $p < 0.001$, $\eta^2 = 0.435$. Under the subheading *Analysis of Pacing Strategies Based on Performance Level,* regarding only female marathon runners, there was a significant interaction between performance level and segment CS, Wilks' $\Lambda = 0.92$, $F (12, 177559) = 499.2$, $p < 0.001$, $\eta^2 = 0.012$. There was a substantial main effect for segment CS, Wilks' $\Lambda = 0.39$, $F (4, 67111) = 28697$, $p < 0.001$, $\eta^2 = 0.138$. The main effect comparing performance groups was significant, $F (3, 67114) = 3019$, $p < 0.001$, $\eta^2 = 0.055$. Significant differences were observed in most performance groups between each segment CS. Regarding only female marathon runners, there was a significant interaction between performance level and segment CS, Wilks' $\Lambda = 0.93$, $F (12, 41512) = 92.92$, $p < 0.001$, $\eta^2 = 0.009$. There was a substantial main effect for segment CS, Wilks' $\Lambda = 0.41$, $F (4, 15690) = 5632$, $p < 0.001$, $\eta^2 = 0.169$. The main effect comparing performance groups was significant, $F (3, 15693) = 757.3$, $p < 0.001$, $\eta^2 = 0.046$. Significant differences in almost all performance groups between each segment CS were found. Concerning the ACS variable, the interaction effect between performance level and sex was significant, $F (3, 82807) = 6.80$, $p < 0.001$, $\eta^2 = 0.000$. There was a significant main effect for performance level, $F (3, 82807) = 2803$, $p < 0.001$, $\eta^2 = 0.091$. All performance groups inside of each sex differ significantly from each other. The main effect for sex was significant, $F (1, 82807) = 1460$, $p < 0.001$, $\eta^2 = 0.016$. In each performance group, male and female participants differ significantly from each other. Under the subheading *Analysis of Pacing Strategies Based on Sex,* there was a significant interaction between sex and segment CS, Wilks' $\Lambda = 0.98$, $F (4, 82810) = 393.2$, $p < 0.001$, $\eta^2 = 0.002$. There was a substantial main effect for segment CS, Wilks' $\Lambda = 0.49$, $F (4, 82810) = 21683$, $p < 0.001$, $\eta^2 = 0.096$. Significant differences between almost each segment inside of each sex were found. The main effect comparing sexes was significant, $F (1, 82813) = 1465$, $p < 0.001$, $\eta^2 = 0.008$. Significant differences between sexes inside each segment were observed. Under the subheading *Analysis of Pacing Strategies Based on Age,* regarding only male marathon runners, there was a significant interaction between age group and segment CS, Wilks' $\Lambda = 0.98$, $F (20, 222576) = 72.23$, $p < 0.001$, $\eta^2 = 0.003$. There was a substantial main effect for segment CS, Wilks' $\Lambda = 0.81$, $F (4, 67109) = 3980$, $p < 0.001$, $\eta^2 = 0.023$. The main effect comparing age groups was significant, $F (5, 67112) = 68.53$, $p < 0.001$, $\eta^2 = 0.003$. Significant differences between most age groups within each segment up to the fifth one, were observed. Regarding only female marathon runners, there was a significant interaction between age group and segment CS, Wilks' $\Lambda = 0.98$, $F (20, 52032) = 13.59$, $p < 0.001$, $\eta^2 = 0.003$. There was a substantial main effect for segment CS, Wilks' $\Lambda = 0.94$, $F (4, 15688) = 249.1$, $p < 0.001$, $\eta^2 = 0.009$. The main effect comparing age groups was significant, $F (5, 15691) = 27.69$, $p < 0.001$, $\eta^2 = 0.004$. Significant differences in most age groups between each segment CS were found in both sexes. Concerning the ACS variable, the interaction effect between sex and age group was significant, $F (5, 82803) = 7.88$, $p < 0.001$, $\eta^2 = 0.000$. There was a significant main effect for sex, $F (1, 82803) = 33.19$, $p < 0.001$, $\eta^2 = 0.000$. Significant differences between sexes in most age groups were observed. The main effect for the age group was significant, $F (5, 82803) = 67.93$, $p < 0.001$, $\eta^2 = 0.004$. Significant differences between most age groups within each sex were found.

In the chapter "**Discussion**", a summary of the main findings of the research was provided. Positive PS with an ES and each segment differing from the next one was observed in almost all runners' subgroups, regardless of the race type, performance group, sex and age. In further subchapters, the author interpreted the analysis of the results. Under the subchapter "**Comparison of Pacing Strategies in the Half-Marathon and Marathon**", the influence of the segment CS was found to have a large practical significance, with only a non-significant difference observed between the fourth and fifth segments of the marathon. Partial validation for Hypothesis 1 was obtained, which suggests that the pacing of half-marathon runners is more evenly distributed compared to the pacing of marathon runners. This validation is based on the significant difference observed in ACS, although the practical significance of this difference was found to be trivial. The substantial decline in speed during the fourth segment across the overall sample was found and can be attributed to the accumulation of fatigue resulting from the rapid initial pace and the extensive distance covered (Cuk, Nikolaidis, & Knechtle, 2019; Hanley, 2015). Considering the shorter race's more pronounced ES and lower average speed compared to the longer race, it suggests a higher proportion of half-marathon participants were beginners and recreational runners, unlike the marathon sample. In the subheading *Comparison Based on Performance Level,* a large influence of performance level on participants' overall speed variability across the races in both sexes was demonstrated. Specifically, faster runners displayed more even PS compared to slower runners, regardless of sex and race groups, which aligns with previous studies (Kais et al., 2019; Nikolaidis & Knechtle, 2017; Piacentini et al., 2019). Regarding male runners in each performance group, half-marathoners demonstrated a more consistent PS compared to marathoners, while among females, the situation was the opposite. Nevertheless, the difference in ACS between races was of minimal importance in both sexes. Based on these results, Hypothesis 1a, according to which the pacing of half-marathon runners is more evenly distributed compared to the pacing of marathon runners in all performance groups of both sexes, was partially validated. One potential explanation for the contrasting results among female runners, in comparison to males, could be attributed to physiological factors (Ansdell et al., 2020; Beltrame et al., 2017; Nuzzo, 2024) rather than psychological (Allen & Dechow, 2023; Dechow & Allen, 2023) and social factors (Proverbio, 2021). Both male and female runners in all performance groups achieved faster average race times in the marathon than in the half-marathon, which is consistent with a study by Yang et al. (2022). Since the sample of half-marathoners had 81% more participants than in marathon, these results can be explained by the fact that an increased number of runners can negatively impact results (Stojiljković et al., 2022; Vitti et al., 2020). Under the subheading *Comparison Based on Sex*, it was found that female runners exhibited smaller ACS in the marathon, whereas male runners showed smaller ACS in the half-marathon race, which is similar to the results of the study by Nikolaidis et al. (2019), but quite different to the study by Cuk, Nikolaidis and Knechtle (2019). The differences between sexes were greater in the marathon compared to the half-marathon race. However, the differences between sexes and races had a trivial practical significance. Based on these findings, Hypothesis 1b was partially validated, indicating that female runners pace more evenly compared to male runners in both races, with differences greater in the marathon than in the half-marathon. Female runners showed less difference in ACS between half-marathon and marathon compared to male runners, potentially due to their higher proportion of type 1 muscle fibers (Nuzzo, 2023, 2024), leading to greater reliance on fat oxidation and reduced utilization of carbohydrates and amino acids compared to male runners (Tarnopolsky, 2008). In contrast, male runners have a higher percentage of type 2 muscle fibers (Nuzzo, 2023, 2024), which rely more on carbohydrates and can result in muscle glycogen depletion (Impey et al., 2020). As races lasting longer than approximately two hours present challenges in fuel availability (Joyner & Coyle, 2008), male runners are more affected in marathons compared to half-marathons. Under the subheading *Comparison Based on Age,* it was indicated that age group significantly influences the overall speed variability of participants in both sexes across the races. Middle-to-quite-older-aged male runners (aged 40–59) and middle-aged female runners (aged 40–49) exhibited a more consistent PS compared to younger and older runners in the half-marathon. In contrast, the situation was quite different among both sexes in the marathon, where the middle-aged group (30–49 age) showed a more even PS than younger and older runners. Very similar results were observed in the study by Cuk et al. (2019). Based on these findings, it was concluded that the specific age groups exhibiting the lowest ACS varied depending on the type of race, but in the half-marathon, it depended on the sex as well. A more evenly distributed PS was observed in the half-marathon compared to the marathon within each age group among male runners. Additionally, the differences between age groups observed in the male marathon runners were a bit greater compared to the male half-marathon runners. However, all of the previously mentioned differences had negligible practical significance. Finally, no significant difference in ACS between races was observed among female runners. Similar results among male runners were observed in other studies (Cuk et al., 2019; Nikolaidis et al., 2019), however, significant differences were observed in female runners as well. Based on these results, a partial validation for Hypothesis 1c was achieved, according to which middle-aged runners pace more evenly compared to younger and older runners, with differences greater in the marathon than in the half-marathon.

Under the subchapter "**Analysis of Pacing Strategies in the Half-Marathon**", it was stated that in the half-marathon each segment was significantly slower than the previous one, except in the fifth segment, where a noticeable ES was observed. The effect size of these differences indicates a large practical significance. Other studies also found positive pacing with an ES in half-marathoners (Cuk, Nikolaidis, & Knechtle, 2019; Cuk et al., 2019), but ES was absent in some of them (Nikolaidis et al., 2019; Nikolaidis, Ćuk, & Knechtle, 2019). Regarding these results, Hypothesis 2, according to which the PS of half-marathon runners is positive, was validated. Under the subheading *Analysis of Pacing Strategies Based on Performance Level*, a large effect size of segment CS was observed across all performance groups. A small effect size, almost reaching the threshold for a medium effect, was found for the differences in CS between each segment among all performance groups in male runners. There were no differences observed between some segments among female runners. The study found a large practical significance of the differences between all performance groups in ACS, regardless of sex, indicating that faster runners demonstrated a more consistent PS throughout the race compared to slower runners. This finding is consistent with the findings of other studies (Piacentini et al., 2019; Hanley, 2015). Regarding these results, Hypothesis 2a, according to which higher-performance-level runners of both sexes, pace more evenly compared to runners of lower performance levels in the half-marathon was partially validated. Additionally, male runners had a more consistent PS compared to female runners within most performance groups, but the differences between sexes had minimal practical significance. Under the subheading *Analysis of Pacing Strategies Based on Sex*, a significant influence of segment CS was found, with a large effect size and discernible differences between each segment. It was observed that female runners showed a slightly larger CS within most of the segments compared to male runners but with negligible practical significance of the differences. Quite different results were found in other studies (Cuk, Nikolaidis, & Knechtle, 2019; Nikolaidis, Ćuk, & Knechtle, 2019; Stanković et al., 2019). Moreover, females exhibited a higher ES compared to male runners. Male runners exhibited a more consistent PS throughout the race compared to females. This was also observed in ACS differences between male and female runners. Based on these results, Hypothesis 2b that female runners pace more evenly compared to male runners in the half-marathon was rejected. Under the subheading *Analysis of Pacing Strategies Based on Age*, a positive PS with an ES across all age groups and both sexes during the half-marathon races was found. The youngest age group showed the most pronounced ES in both sexes, with female runners showing a more pronounced effect. Significant influences of segment CS were found in both sexes, although their practical significance was small. The differences between each segment CS were observed within almost all age groups, except for the two oldest groups in both sexes. Furthermore, a significant influence of age group on CS_{1-5} was identified, although the practical significance was negligible. Differences were observed between most age groups within each segment. The results indicated that both sex and age group had a significant influence on the ACS, although the practical significance of sex was negligible and almost reached the threshold for a small effect for the age group. Female runners exhibited higher speed variability throughout the race compared to male runners across the ages of 40–69. However, within the age group of 30–39, the situation was reversed, indicating a slight increase in speed variations among male runners. Notably, middle-to-quite-older-aged male runners (aged 40–59) and middle-aged female runners (aged 40–49) exhibited a more consistent pace compared to both younger and older age groups. Very similar results regarding female runners were found in the study by Nikolaidis et al. (2019), while among male runners some differences were observed. Contrasting results regarding female runners were found in the study by Cuk et al. (2019), while similar findings were found among male runners. Taking all of these results into account, these findings provide partial support for Hypothesis 2c, suggesting that middle-aged runners of both sexes pace more evenly compared to younger and older runners in the half-marathon.

Under the subchapter "**Analysis of Pacing Strategies in Marathon**", a large practical significance was observed in the differences between the mean speeds of each segment. All marathoners exhibited a decrease in speed up to the fifth segment, followed by an increase in the fifth segment, indicating a prominent ES. These findings align with other mass participation studies (Cuk, Nikolaidis, & Knechtle, 2019; Cuk et al., 2019; Nikolaidis et al., 2019; Nikolaidis, Ćuk, & Knechtle, 2019; Cuk et al., 2021). Based on these results, Hypothesis 3, according to which the PS of marathon runners is positive was validated. Under the subheading *Analysis of Pacing Strategies Based on Performance Level,* the influence of segment CS was found to be substantial, with a large practical significance, indicating differences between each segment CS in both sexes. There was a significant impact of performance group on segment CS, although the practical significance was small, almost reaching the threshold for a medium effect. The influence of performance level on ACS had a medium practical significance. These findings indicate that faster runners exhibited a more even pace throughout the race compared to their slower counterparts. Differences between almost all segment CS were observed among all performance groups in both sexes. Female runners generally showed a more consistent PS within each performance group, although the practical significance of these variations was limited. ACS decreased as the runners' performance level increased in both sexes, which is consistent with the results of other studies (Cuk et al., 2021; De Leeuw et al., 2018; Hubble & Zhao, 2016; Kais et al., 2019; Nikolaidis & Knechtle, 2019; Stojiljković et al., 2020). Based on these results, Hypothesis 3a, according to which higher-performance-level runners of both sexes, pace more evenly compared to runners of lower performance levels in the marathon, was confirmed. Under the subheading *Analysis of Pacing Strategies Based on Sex,* a positive PS with an ES was observed in both sexes, with the ES being more pronounced in female runners. Similar PS was observed in other mass participation studies (Breen et al., 2018; Casado et al., 2021; Cuk, Nikolaidis, & Knechtle, 2019; De Leeuw et al., 2018; Nikolaidis, Ćuk, & Knechtle, 2019). Contrasting findings emerged for world record holders demonstrating both, a negative (Díaz et al., 2019) and an even PS with an ES (Muñoz-Pérez et al., 2023). A significant influence of segment CS was found, with a medium practical significance. Almost every segment showed significant differences from one another in both sexes. Female runners exhibited smaller CS in each segment compared to male runners, indicating a more consistent

PS. However, the differences between sexes had minimal practical significance. Similar findings were also observed in ACS differences between sexes. Previous studies reported similar differences in PS between sexes among non-elite marathon runners (Cuk, Nikolaidis, & Knechtle, 2019; Kais et al., 2019; Nikolaidis, Ćuk, & Knechtle, 2019; Stojiljković et al., 2020). It was assumed that these differences can be attributed to physiological factors, such as lower susceptibility to fatigue in female individuals (Hunter, 2014, 2016), possibly due to a higher proportion of type 1 muscle fibers (Nuzzo, 2024) that rely more on fat oxidation, contributing to reduced reliance on carbohydrates and amino acids compared to male individuals (Tarnopolsky, 2008). Based on these results, partial validation for Hypothesis 3b, according to which female runners pace more evenly compared to male runners in the marathon, was obtained. Under the subheading *Analysis of Pacing Strategies Based on Age*, significant differences were observed between almost every segment CS among all age groups in both sexes. Age group was found to have a significant influence on segment CS as well. The highest ES was noticed in the youngest age group among male runners, while both the oldest and youngest age groups exhibited a higher ES compared to others among female runners. Female runners demonstrated lower ACS and, consequently, a more consistent PS compared to male runners across all age groups up to the age of 69. The significant influence of age group on ACS was demonstrated by the middle-aged runners (30–49 years old) exhibiting a more even PS compared to the younger and older runners in both sexes. These findings are consistent with other studies on the same topic (Cuk et al., 2021; Cuk et al., 2019; Nikolaidis et al., 2019; Nikolaidis & Knechtle, 2018a, 2019). These results may be atributed to physiological and morphological changes in older runners (Lee et al., 2019; dos Anjos Souza et al., 2023; Visser, 2021) and lower aerobic capacity and limited running experience in younger runners (Deaner et al., 2015). However, despite the minimal or trivial practical significance of all these differences, partially validation of Hypothesis 3c was obtained, suggesting that middle-aged runners of both sexes pace more evenly compared to younger and older runners in the marathon.

In the chapter "**Limitations of the study and future research**", the author states that one limitation of this study is the absence of supplementary information such as prior training regimen, experience in distance running and racing, or anthropometric characteristics. It should be noted that over the 17 years of the Vienna City Marathon, performance groups were established, but variations in weather conditions and participant numbers across different years could potentially impact the consistency of these divisions. The author suggests that future research could incorporate such analyses and also examine the PS of non-finisher.

In the chapter "**Potential significance and practical application of the research**", the author notes that half-marathon and marathon running is a popular global activity, growing in participation annually. Since PS plays an important role in reducing the risk of significant homeostatic imbalances and achieving results in these disciplines, the analysis of these strategies has significant practical implications. The study's inclusion of a substantial portion of international runners in the Vienna City Marathon eliminates the impact of a single nation, and the large, diverse sample likely represents the entire runner population, allowing for the generalization of the findings.

The novelties of this study are:

1. Analysis of a large sample of participants.
2. Analyses of half-marathon PSs were conducted by considering three factors: performance levels, sex and age – an approach adopted due to the limited availability of studies incorporating these specific factors in the context of half-marathons.

3. Comparison of half-marathon and marathon races held on the same day, on the same track, and under similar external conditions.
4. Analysis and comparison of half-marathon and marathon PSs were conducted based on three factors: performance level, sex and age.

The even pacing profile observed across different editions of the same race enables effective PS to be planned. The research results may provide valuable information to experts, coaches, athletes, and recreational runners when it comes to controlling fatigue during efforts to achieve the best possible race results. A specific approach should be adopted to the entire training process, individual training sessions, and races based on these subcategories. One approach is to educate subcategories lacking knowledge and experience in PS during long-distance races. Since the majority of participants in mass races are recreational runners, it is crucial to educate them properly so that running helps enhance their well-being in terms of health and quality of life rather than the opposite. This way, negative health consequences resulting from poor PS would be avoided, and the motivation of runners to continue engaging in running would be increased. Training runners to maintain an even pace is crucial. This optimizes energy utilization and prevents early depletion or overly conservative pacing, which hampers performance and may result in compensatory "end spurts". The focus should be on the youngest male and female half-marathon runners, along with the slowest runners in that category, as they are of utmost importance. Since achieving an even PS can be challenging to master, it is advisable to suggest beginners and less experienced recreational runners maintain a negative PS. Since PS also depends on external conditions, the research results could be significant in choosing a race where the runner could achieve the best result based on terrain configuration, weather forecast, time of year, etc. Equipped with proper knowledge and skills, runners can choose an optimal pace and stick to their planned strategy. By considering internal and external factors, they can accurately gauge their capabilities and achieve the desired outcome. This approach reduces reliance on other runners' paces, which may hinder maintaining an optimal pace throughout the race.

In the chapter "**Conclusions**", the author draws conclusions. Under the subchapters "**Comparison of Pacing Strategies in the Half-Marathon and Marathon**", "**Analysis of Pacing Strategies in the Half-Marathon**" and "**Analysis of Pacing Strategies in the Marathon**", the author states that a positive PS with an ES and varying segments was observed in almost all runner subgroups, regardless of the race type, performance group, sex, and age. Faster runners exhibited a more consistent PS compared to slower runners. Slower runners had a higher ES compared to faster ones. Significant difference in ACS between races within each performance group was observed. Male runners had lower ACS than female runners in the half-marathon, while the opposite trend was observed in the marathon. The differences between sexes were more pronounced in the marathon compared to the half-marathon. Female runners showed a higher ES than male runners. In the half-marathon, male runners aged 40–59 and female runners aged 40–49 exhibited a more evenly distributed PS compared to younger and older runners. In the marathon, runners aged 30–49 showed a more consistent PS regardless of sex. Among male runners, each age group displayed a more even PS in the half-marathon compared to the marathon, while no significant difference was found among female runners. In the half-marathon, the youngest runners, regardless of sex, exhibited the fastest ES. In the marathon, the fastest ES was displayed by the youngest male runners and by both the oldest and youngest female runners.

The **References** chapter includes a total of 264 bibliographic entries, with the majority being published in prominent international scientific journals. Thirteen of them are internet websites.

Bibliographic units are correctly listed in the text and the bibliography. The majority of the references were published within the last ten years.

Other attached documents are the candidate's biography, candidate's bibliography, Approval of the Ethics Committee, Published research of the candidate as the first author, Statement of authorship, Statement on the identity of the printed and electronic version of the doctoral thesis, and Statement of Use.

Opinion and Proposal of the Commission

Ljubica Ristanović's doctoral dissertation is written in English. The research has the following main aims: 1. Comparison of pacing strategies in half-marathon and marathon runners; 2. Analysis of pacing strategies in half-marathon runners; 3. Analysis of pacing strategies in marathon runners. The research is formulated based on a careful analysis of extensive bibliographic material. The research problem is thoroughly explained, and the aims and hypotheses are clearly formulated. The research methods enabled the achievement of the research aims.

The research is highly significant both theoretically and practically. The findings have valuable applications for experts, coaches, athletes, and recreational runners in managing fatigue during long-distance running for the best possible race results. A tailored approach can be adopted for the entire training process, individual sessions, and races, considering factors such as race type, performance level, sex, and age. One approach involves educating subcategories lacking knowledge and experience in pacing strategy for long-distance races. Since the majority of participants in mass races are recreational runners, the research can be applied to educate them effectively, promoting their well-being and quality of life through running. This would help prevent negative health consequences resulting from poor pacing strategy and increase runners' motivation to continue their engagement in running.

We propose that the Teaching and Scientific Council accepts the Commission's report and sends a decision to the Council for Scientific Fields of Social Sciences and Humanities, approving the defense of Ljubica Ristanović's doctoral dissertation entitled: "**Pacing strategy in half-marathon and marathon based on performance level, sex and age (Strategija tempa trčanja polumaratona i maratona u zavisnosti od takmičarske uspešnosti, pola i starosti)**" and appointing full professor Stanimir Stojiljković, PhD, from the University of Belgrade – Faculty of Sport and Physical Education and assistant professor Ivan Ćuk, PhD, from the University of Belgrade – Faculty of Sport and Physical Education, as mentors.

In Belgrade, on April 26th, 2024.

Commission Members:

Associate professor Milan Matić, PhD, University of Belgrade – Faculty of Sport and Physical Education, Belgrade, Serbia, commission president;

Associate professor Igor Ranisavljev, PhD, University of Belgrade – Faculty of Sport and Physical Education, Belgrade, Serbia, member;

Associate professor Vladimir Mrdaković, PhD, University of Belgrade – Faculty of Sport and Physical Education, Belgrade, Serbia, member;

Associate professor Miloš Marković, PhD, University of Belgrade – Faculty of Sport and Physical Education, Belgrade, Serbia, member;

Full professor Beat Knechtle, PhD, Institute of Primary Care, University of Zurich, Zurich, Switzerland, member.