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Investigation of psychophysiological elements in technical sports, among junior athlete

Doctoral (Ph.D.) thesis

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Pécs, 2024

INTRODUCTION

Motorcycle sport is popular around the world, currently 118 national motorcycle associations on six continents belong to the International Motorcycle Federation (FIM), (including the Hungarian Motorsport Association (MAMS), which is recognized by the International Olympic Committee as the sole competent authority for motorcycle sport. In seven different disciplines (speed, motocross – supercross and supermoto, trial, enduro, off-road, dirt bike and E-bike) organize competitions at local, national and international level (FIM, 2023).

The topic of my doctoral thesis is also related to technical sports, as I have been active in motorsport in many areas for the past 30 years. During my research work, anthropometric, physiological, heart rate pattern analyses are found among adolescent and adult motorcycle racers; examination of the physiological and cognitive characteristics of motocross riders during competitive stress; the load-physiological characteristics of skill off-road motorcycling as a result of competitive load; and the load physiology aspects of Superenduro GP world competitions.

Motocross is a motorcycle cross-country race where the performance can usually be summed up as the interaction of the rider, the motorcycle, and the environment. In this sport as well, there is a significant physiological, mechanical and psychological effect on the competitors. During the external and internal forces affecting the athlete on the motocross track, serious concentration, low reaction time, fast reflexes and task recognition, as well as significant physical and mental endurance are also necessary for successful racing, so in addition to the availability of the most modern motorcycle technology, the individual performance of the athlete is particularly decisive (D' Artibale et al., 2017; D'Artibale et al., 2018).

My goal with the doctoral thesis was to contribute to the further development of Hungarian motorsport with the knowledge and research I acquired and applied in my field, and to present directions suitable for further thinking for the domestic actors of the sport.

OBJECTIVES

The purpose of the thesis is to describe and compare the characteristics of the anthropometric and physiological (circulation-metabolism), upper and lower limb muscle strength measured in laboratory and competition conditions, and their differences in adolescent male MX competitors who are listed on the international ranking list and who are successful in their age group in domestic competitions. Its purpose is also to analyze the heart rate (HR), speed (V) and cadence recorded during the race - following the joint movements of the ground and the engine (K) during riding, their pattern, as a characteristic of possible effectiveness. The doctoral thesis also examines the affective anxiety-related characteristics of the competitors (enjoyment, tension, control and the stress-inducing effect before and after the competition).

We want to achieve our goals by answering the following questions:

Does the difference in the structural and body composition characteristics of children with almost the same chronological age influence successful competition in early adolescence?

A similar question needs to be formulated regarding the physiological differences, if/and if there is a difference between the two groups. Namely, whether the current circulatory-respiratory system and metabolic characteristics influence more successful competition performance (VO_{2max}, VCO_{2max}, RER).

In addition to the analysis of motorcycling technique, tactical discipline during the race, the continuous following of the competitors, and the appropriate response to their expected line selection, the examination of the psychophysiological characteristics of the competitors is particularly important. Together, these can provide an answer to what makes someone successful in off-road motorcycling.

HIPOTHESIS

1. Among the anthropometric characteristics, an important element is the definition of the somatotype. Anthropometric somatotype can be synonymous with phenotypic morphological structure. The morphological structure is particularly important from the point of view of the effectiveness of the sport we are examining. We assume that of these, the central part can contribute the most to successful racing.
2. The above-mentioned body type can mean a chance for more successful racing. From a human biological point of view, this means that one of the important requirements for more successful motorcycling is a greater share of lean body mass in the total body mass. We assume that more successful competitors have a higher lean body mass than their less successful contemporaries.
3. Motocross takes place on natural and man-made terrain, overcoming many obstacles: uphills and slopes, jumps are a serious strain on both the motorcycle and the rider. The competitor is sitting on the motorcycle and the engine does the work. However, the rider must steer the motorcycle, which is 85-110 kg, in contrast to the mass of the riders we examined, who weigh (~60 kg). You have to react quickly to the powerful and sudden movement of the motorcycle, which requires dexterity, muscle strength and endurance. Based on these, we assume that the effective performance of the tasks described above requires muscles of high quality and condition, whether we are thinking of the condition of the upper or lower limb. In addition to fitness, the symmetrical load ability of the large limb muscles mentioned above should be treated as an important aspect. We assume that the muscles of the upper arm and lower limb (approach - abductor) of the adolescent competitors tested in laboratory conditions respond symmetrically to the single load, and that the relationship is significant in the function of the lower and upper limbs of the internationally registered competitors.
4. In motocross, the heart rate is usually higher than 80% of the theoretical heart rate and is kept at a fairly high level for the duration of the race. We assume that the maximum heart rate measured in the laboratory is reached by the competitor in several cases, either during free and time trial training or during "sharp" races.

5. Anaerobic periods of alternating duration were found during the test until complete exhaustion in the exercise physiology laboratory. We assume that the averages of the respiratory coefficient (RER) of the two groups of the more successful competitors are significantly higher than those of their contemporaries in the domestic field.
6. The rest time between the first and second race is barely two hours. The averages of the regeneration time per group are much higher, even 3-4 times. We hypothesize that the time spent in the intensity zones will shift in favor of the lower zones in the second run.
7. The central tenet of the (IZOF) model is that each athlete has an individually pre-optimal performance bandwidth (zone/range) in anxiety intensity, within which the best performance is most likely. We assume that the above-mentioned bandwidth is narrower for those competitors who performed more effectively (achieved a better position) during the races.
8. The speed changes according to the terrain conditions - higher on longer straights and lower on sections with turns. We assume that, at the same time, the heart rate pattern also changes along with the speed, i.e. during or after the highest speed section of the track, the athletes' heart rate also increases/decreases as a result of the external and internal forces acting on them.

MATERIAL AND METHOD

Test protocol

The test was carried out in 2021, which included laboratory and track tests. All laboratory tests were carried out in the last month before the start of the championships, at the end of the competitors' preparation period. The motocross competitors visited the laboratory once, where the anthropometric characteristics were first recorded, and then the hip and shoulder muscle strength was measured. Finally, the capacity of the circulatory and respiratory systems was tested on a treadmill ergometer by monitoring the heart rate, according to the planned protocol. The laboratory tests took place between 12:00 p.m. and 4:00 p.m. and were carried out by the same testing team that also participated in the track test. The lab tests took place during this time interval, because the participants' sport-specific training and competitions are mainly held at this time of day. Participants were asked to refrain from vigorous physical activity in the 24 hours prior to the laboratory examination, arrive rested, and adhere to dietary guidelines. The tests were preceded by a professional warm-up and ended with stretching.

People included in the study

Fourteen Hungarian elite motocross riders were included in the study. Their anthropometric characteristics were as follows: age (Group 1 = 14.0 ± 2.3 years), body height (166.2 ± 6.3 cm), body weight (58.1 ± 5.1 kg), BMI (20.5 ± 1.7 kg/m2); age (Group 2 = 13.2 ± 2.2 years), body height (150.3 ± 18.3 cm), body weight (51.4 ± 8.4 kg), BMI (20.1 ± 4.3 kg/m2). As I described, the subjects trained and competed regularly, so we only explained the main goals of the research to them, and the parents filled out a consent form. We created two groups, Group 1. (N=5 people) – international ranking list and Group 2 (N=9 people) – young motorcyclists included in the national ranking list. Group 1 was made up of riders who have been riding motorcycles with the help of their families since childhood (age 5-7). Based on the official register of the Hungarian Motorsport Association, the number of certified junior motocross racers in the year of the study was 83, in four categories (Mx50, Mx65, Mx85, MxWomen). The athletes we examined started in the MX 85 machine class, in which there were a total of 32 certified competitors that year. Out of these 32 contestants in total 20 people entered the examined competition, of which 17 were Hungarian athletes. In this category, together with the foreign competitors, 30 people stood behind the starting gate. In summary, this indicates that the 15 people we examined represent 50% of the entire field, and the investigation covered 88.24% of the Hungarian competitors. The participants all regularly perform integrative and sport-specific training, based on a personalized, pulse-controlled training plan, and compete in national and international age-group, regional and championship-level competitions. Among them, you can find the most successful junior Hungarian champions, Junior European Championship and World Championship podium athletes, as well as less successful amateur level athletes. They have been practicing their sport for an average of 6.26±3.4 years.

Ethics approval

The research was conducted in accordance with the guidelines and guidelines of the Health Science Council, Scientific and Research Ethics Committee (IV/3067-3/2021/ EKU) and the Declaration of Helsinki. All involved participants are certified members of the Hungarian Motorsport Association through their sports association. He gave his voluntary consent to participate in the study, while the parents indicated their consent with their signatures.

Presentation of the rules of the competition

The track tests were conducted at the opening race of the Hungarian Motorsport Association's national championship series in the junior MX85 machine class. The competition consisted of two races of 15 minutes each + 2 laps, preceded by a 15-minute free practice session in the morning and a 15-minute time trial session. The rest period between the four time races was at least one and a half hours. The start starts from a single line, and the winner of the race will be the one who collected the most points based on the two races. If there is an exact match between two or more competitors based on the two races, the better result belongs to the one whose second race result is stronger.

Dimensions of the racetrack

The test took place on the FIM-registered sports track of the Piliscsév Motorsport Centrum Hungary in the village of Piliscsév, Pest County, suitable for holding national and international events. Length of the race track: 1990 m, average width: 6-8 m, level difference: 30 m, number of jumps: 14, number of turns: 13, track surface: clay, sandy ground, soil quality: irrigated, optimal.

Course tests

Timing, evaluation, preparation of results in the competition

The official timing of the race was carried out by a timing team with domestic and international experience, operating in the field of automobiles and motorsport, using the transponder/chip (beacon) attached to the racing engines and the photocell signal recording system (accuracy of 0:00.001) placed on the finish line. We processed the data obtained in this way, lap times, training and race results.

Track race performance with Polar Team Pro telemetry

The MX competitors took part in two consecutive training sessions and races of a domestic competition. The competition took place on the indicated track in the spring of 2021. The weather conditions were optimal and the level of preparation of the competitors was similar. Heart rate (HR), speed (V) and cadence (K) patterns were recorded using the Polar Team Pro® system (Polar Electro, Kempele, Finland). The system consists of a chest belt containing a sensor unit (Polar H7 Bluetooth 4.0 smart chest strap) with built-in ECG electrodes. The device has a 10Hz integrated GPS and a 200Hz MEMS motion sensor. With the help of an adjustable neoprene strap, the devices were placed on the front part of the chest of each competitor 30 minutes before the time trials, so the preparation before the time trials (dressing, warm-up, lead-up lap) was already recorded by the device. This procedure allows the 12 satellites to be connected and fixed and synchronized with the software.

Application of a psychological questionnaire on the current cognitive anxiety state related to racing

During the research, we formulated seven questions using the individual zones of optimal functioning (IZOF) model (Robazza et al., 2004). Three questions before the race and four questions shortly after the race. The answers to the questions had to be marked on a scale of 10. We uploaded the questionnaire to the contestants' phones and completed the task using it.

Serum lactate measurements before and after the competition

Blood lactate concentration was evaluated to determine metabolic responses before and after the exercise test performed in the laboratory and the time trials of the competition. Blood samples (25 µl) were taken from the fingertips in heparinized capillary tubes and then transferred to microtubes containing 1% sodium fluoride (50 µl). Lactate concentration was analyzed using an electro-enzymatic method (YSI 2300 Stat Analyzer, Yellow Springs Instruments, Yellow Springs, OH, USA) before and after the first (F1) and second (F2) races. Blood lactate concentration was expressed in mmol/L.

Laboratory tests

Anthropometric characteristics and determination of body composition

The anthropometric characteristics were performed by a trained ISAK-accredited expert (level 1) based on the standardized procedures of the International Kinanthropometric Society, using certified Sieber-Hegner measuring devices (anthropometer, pelvic girder with 60 cm opening distance, Holtain calliper, steel measuring tape with adapter, Lange skin fold gauge caliper). We used a personal scale with a digital display (reading accuracy: 0.1 kg) to determine body weight. To determine the somatotype (Heath & Carter, 1967), we recorded data at 24 points on the athletes' body surface. The body composition test was performed with a Seca mBCA 515 type bioimpedance analyzer.

Examination of the characteristics of the circulatory and respiratory systems

The characteristics of the circulatory and respiratory system were performed in the Exercise Physiology Laboratory of the Fehér Miklós Football Academy using a Piston-type instrument (EN ISO 13485:2016, Budapest, Hungary). Ergo-spirometry tests were performed before the start of the competitive season, following a progressive intensity protocol until voluntary exhaustion, on a treadmill (Pulsar 4.0, h/p/Cosmos Sports & Medical 0; GmbH, Nußdorf, Germany). During the study, the recorded circulation and breathing characteristics were used for the initial profile of the Polar Team Pro (resting heart rate of the competitors - HRrest), the maximum heart rate (MP) and the identification of the two breaking points (RCP, VT) in the interpretation of the data recorded during the race (Astrand & Rodahl, 1986).
During the study, heart rate (HR) (Garmin HRM3-SS. Garmin Ltd. Olathe. KS. USA) was recorded using a chest transmitter and receiver. We monitored oxygen uptake (VO2) and carbon dioxide release (VCO2), as well as the change in the ratio of the two metabolites (VCO2/VO2). The value of VO2max is acceptable if at least the following three criteria are met:
(1.) The heart rate (HR) in the last minute exceeds 95% of the maximum heart rate (HR) of the subject, which was previously determined in various ways.
(2.) VO2max levels off (plateau) despite increasing treadmill speed, VO2<150 ml O2 (Brink-Elfegoun, 2007).
(3.) The respiratory gas exchange ratio (VCO2/VO2) reached or exceeded the value of 1.1 (Astrand & Rodahl, 1986), and the subjects were unable to continue running despite verbal encouragement. The resting heart rate (HRrest) was measured in laboratory conditions by averaging the data of the last 5 minutes of the 20-minute sitting rest conditions.

Examination of the strength of both thigh and arm abductor and abductor muscles

Hip and arm isometric strength was measured using the "ForceFrame®" Strength Testing System (VALD Performance Pty Ltd., Brisbane, Australia) according to a strict protocol (Impellizzeri et al., 2007; Kadlec et al., 2021). For the execution, the participants were asked to lie on their back under the system. With the outside of both knees placed on the padded load cell (100 Hz) at a 60◦ angle (hips flexed at 60◦). The participants first received a presentation from the examiners and then performed a warm-up exercise. Participants were first required to perform an isometric contraction of the hip adductor (AD) for 5 seconds, followed by a 5-second isometric contraction of the abductor muscle (ABD) after a 5-second rest period. After the 45-second rest period, the same procedure was repeated, the results were automatically saved by the iPad. Hip strength (ABD) and (AD) was determined based on the maximum peak force (N) of three trials. These values were then converted to joint torques (N/m) based on the length of the right lower leg (the distance between the anterior upper iliac bone and the lateral ankle bone).

Statistical analysis

The anthropometric, body composition and cardiorespiratory, hip and arm isometric strength characteristics of the two groups, as well as the difference between the averages of heart rate (HR), speed (V) and cadence (K) of the competitors recorded in the first and second races, were compared using a two-sample t-test . Hedges g' effect size was calculated by taking the difference between the averages between the two groups, and then dividing the result by the pooled standard deviation. During the statistical analyses, the result was considered statistically significant if the fixed level of alpha was 0.05. The difference between the 1st and 2nd races per lap, per person (comparison of 15 persons – percentage difference): the difference between the two races of a given person expressed in %, per lap, was examined. Before and after the free training: "enjoyment", "tension", "control" characteristics (with a non-parametric test of relatedness) were analyzed with the Wilcoxon test. An analysis of variance (ANOVA) was performed to compare the maximum heart rate (MP) and maximum speed (Mspeed) medians recorded during the free and time trial training and the races. Pearson's correlation was used to compare the arm and leg muscle strength of the two groups. Affective anxiety patterns of successful and less successful competitors and locomotor performance recorded during the two races and its mechanical characteristics were compared with a two-sample t-test. Statistical analyses were performed with IBM SPSS Statistics for Windows, Version 25.0 (IBM Corp. Released 2017. Armonk, NY: IBM Corp.).

RESULTS

Anthropometric and physiological characteristics of children's motocross (MX) competitors

There was no statistically significant difference between age ($t=0.61$, $p=0.559$) and the other examined anthropometric and physiological characteristics, except for body weight, between the MX competitors on the international (group 1) and national (group 2) rankings relative muscle mass and lean body mass M% ($t=1.761$, $p<0.001$); regarding LMB ($t=2.034$, $p<0.000$). The body type of the examined competitors is "endomorphic - mesomorphic", which means that II. component is dominant, I. and III. the difference between component values is less than 0.5 units. Comparing the maximum strength of the right- and left-leg abductor-proximity muscles of the two groups of competitors, no significant difference was found in any of the examined characteristics. Performances are symmetrical on both the right and left sides. During the first race (MX), group 1 competitors stayed in the HR(90-100%) intensity range for a significantly longer time ($p=0.034$, $t=1.65$) and reached a higher maximum top speed ($p=0.027$, t=2 .93) than the 2 groups. Surprisingly, during the second race, the competitors of group 2 (MX) spent significantly longer in the HR (90-100%) intensity range ($p=0.041$, $t=-1.53$) and completed a significantly shorter sprint distance ($p=0.002$, $t=2.68$). No significant difference was found between the maximum speed averages. Of the thigh and arm abductor and abductor muscles on both sides measured in the laboratory (Force Frame, Vald) in the first group, the right/left arm ($r=0.991$, $p<0.001$);

right/left leg and distance approximation values (r=0.998, p<0.002) show a statistically significant, very high (deterministic), positive relationship. In the second group, there is not a relationship in all cases (it does not show a significant relationship with several values of the approximation), and the relationships are of lesser strength. Physiological characteristics achieved in the laboratory (VO2max, VCO2max, O2P, PO) and characteristics recorded during MX competitions (HRrest, HRmax, HR(70-80%), HR(80-90%), HR(90-100%), Regarding the relationships between Sebmax, Sebavg, Cadence, Sprints) in the first group, there was a significant negative correlation between HRrest and O2P (r=0.975, p=0.005) and PO (r=0.999, p<0.001) averages. We also found a significant correlation between HRmax and maximum oxygen uptake - VO2max (r=0.911, p=0.032). Among the MX riders belonging to the second group, however, we found only one relationship between HR (70-80%) and O2P (r=-0.673, p=0.047).
Comparing the results obtained during the second run (F2) with the laboratory results, similar relationships were found in the first group, i.e. a significant positive correlation between resting heart rate (HRrest) and pulse volume (O2P) (r=0.875, p=0.005), as well as performance (PO) (r=0.897, p<0.001). A significant correlation was found between HR(70-80%) and VCO2max (r=0.541, p=0.035), and between HR(90-100%) and VO2max (r=0.853, p=0.005). Among the MX competitors of the two-person group, only HR (70-80%) showed a significant relationship with the value of VCO2max (r=0.647, p=0.005). It shows the differences in serum lactate concentration between the first and second groups, after the first (F1) and the second run (F2). Before the F1 and F2 races, there was no statistically significant difference in the lactate concentration of the first and second groups (> 0.05). After F1 and F2, delta-lactate showed no statistically significant difference between the first and second groups [t(12) = 2.074, p = 0.086 and t(12) = (-1.036), p = 0.329]. In the first group, the concentration of SLL was significantly higher (3.8 mmol/L, p = 0.028] after F1, while there was no significant difference between the SLL values before and after F2. In the second group, the differences in SLL concentrations before and after F1 they were at the limit of significance (p = 0.053), with a value of 1.8 mmol/L. Similar to the first group, there was no significant difference in the SLL values before and after F2 in the second group. The SLL values were also lower in both groups after the second competition.

Heart rate pattern analysis in a competitive situation

In the first race, the percentage averages of the heart rate per lap of the three competitors varied between (92-100%), in the second race (92-97%). In the seventh and eighth rounds, we found a significant difference in favour of the first race (1st race/7 rounds= 98.67±2.52-2nd race/7 rounds=94.00±2.00); p<0.005; (1st race/8 laps= 99.33±2.08 – 2nd race/8 laps=94.00±3.46); p<0.026. The difference in the averages of the two races increases continuously from the seventh round. The difference is due to the significantly higher values recorded in the first run compared to the second run. The speed averages between the third, ninth and eleventh lap signal the difference is huge. The difference in the averages can be written in favour of the second race in the third and ninth rounds, while the first race in the eleventh. In the case of cadence, numerically higher values were found in the second race until the fifth lap, and then this trend changed in the opposite direction. There is a significant difference in the seventh (102.8±2.5 – 97.1±2.6); p=0.042 and in the tenth round (100.0±1.5 – 102.5±1.8); we have found p=0.013 between races. At the start of the race, the heart rate was at 68% of the load. A significant sympathetic effect is observed. Shortly after the start (one and a half minutes), the heart rate increases to 97% of the maximum value and this value varies between 3-7%. At the same time, the speed of progress increases, which is the highest in long straight sections, while in bends and up hills, it can be reduced by almost half. Increases and decreases in speed are not accompanied by significant fluctuations in heart rate. The degree of fluctuation varies between 5-8 beats×min-1. There is a 3-4% difference between the heart rates of the two races in favour of the first race until the middle of the race, and then a significant increase can be observed from the second half of the first race. From this point, the values of the first run exceed 100%, while the same section of the second run varies between 94-92%. The pattern of the heart rate of the second competitor is similar to the values of the first competitor in the first race, while in the second race the values of the second competitor decreased continuously, already from the fourth lap of the race. The third competitor reached 92% of the maximum heart rate at the beginning of the first race, and it steadily increased from the third round until it reached 100%. It decreased again from the seventh round until the end of the race. The decrease was not significant ~2%. The start of the second race began with a particularly high heart rate, and then continued with a relatively balanced load, albeit with a slight decrease. As for the speed pattern calculated per lap of the two races, the difference between them is minimal. In almost all cases, the speed averages achieved in the second round are ahead of those achieved in the first round. The averages of movements recorded during the competition reached, and in several cases even exceed 100. We observed two significant drops at the beginning of the first race, in the third-fourth round, and in the middle of the second race, in the sixth round.

Comparison of free training and competition heart rate patterns

Based on the results recorded with the "Polar Team Pro" telemetric device, the difference between the maximum heart rate averages during free training and the following competition is significant [F(1;28)=4.732; p<0.038)]. Whether we look at the difference between the medians or the quartiles, the difference between them (~8 strokes×min-1) is in favour of the average performed in the competition. The maximum speed averages differ only numerically. If we look at the time spent in the (70-80%) and (80-90%) intensity zones, the competitors spent more time here during free training before the competition. The median time for free exercise in the (70-80%) intensity zone (Me=234.5 sec.). The value belonging to the first quartile (Q1) is (202.3 sec.), while the value belonging to the third quartile (Q3) is (267.5 sec.). The median recorded during the race was similar (179.2 sec.). Similar results were found in the (80-90%) zone. However, in the (90-100%) intensity zone, the difference between the two medians is significant [F(1;28) 5.203; p<0.030]. The number of sprints examined in the two situations is significantly different, it is higher in the competition situation (Me=197.7 pcs.) than during the preceding free training (Me= 111.2 pcs); [F(1;28)=22.113; p<0.0000)]. Regarding the number of movements performed while riding a motorcycle (riding), the difference between the medians in the two examined situations is also significant [F(1;28)=8.766; $p<0.0062$)]. The difference between the average speed achieved during the two activities and the medians of the regeneration time is significant in both characteristics. During free training (Me=23.12 km×h-1), during the competition (Me=35.91 km×h-1), [F(1;28)=13.60; $p<0.0010$)]. The regeneration time considering the load of free training (Me=7.32h), and the competition load (Me=21.87h) was calculated for rest [F(1;28)=86.59; $p<0.0000$)].

The results of the psychological questionnaire on the current affective state of anxiety related to the competition carried out on the day of the competition

During free training, tension was marked in a significantly higher proportion after it ($U>E=75.0\%$); (Z= -2.136), $p<0.033$ than before. The values of pleasure and control before and after it are not significant. Pleasure was present in a higher proportion before ($U<E=62.6\%$) than after ($U>E=25.0\%$). As for management, it was evaluated in a higher proportion after than before ($U<E=62.5\%$). Enjoyment appears significantly higher after the time trial training than before ($U>E=75.0\%$), (Z= -2.116), $p<0.034$. Tension and control showed no significant difference before and after the time trial training. Tension was more present before than after ($U<E=50.0$), while control was more present before than after ($U<E=85.7$). In the first race, it is one but no significant difference was found in the examined psychological elements either. Pleasure was more present before than after ($U<E=71.4\%$), while tension was more present after than before ($U>E=71.4\%$). As for the management characteristic, it was in a higher proportion after than before ($U>E=57.1\%$). In the second race, neither before nor after, we found no real difference in any of the elements. Pleasure is evaluated as greater before or after it in the same proportion, while tension, which is evaluated in the same proportion or after, as greater or unchanged. Control appears in a higher proportion before it than after it ($U<E=60.0\%$). A significant negative relationship was found in the first race between the tension before F1 and the averages of the 70-80% intensity zone (r=-0.689); $p<0.047$. In the second race, there is a significant relationship between F2 and the 70-80% intensity zone averages (r=0.951); $p<0.013$, or between enjoyment before F2 and the number of sprints (r=-0.912); $p<0.002$ with a negative sign. During the free training, of the 8 competitors interviewed, enjoyment as a psychological element increased only in the case of two competitors. In the case of voltage, it increased in all but one competitor. Control has a similar pattern to tension, followed by the stress-causing element, except for two competitors, it is negative, showing a significant decrease in three cases. During the time trial, enjoyment as a psychological element increased significantly for almost all competitors interviewed, although this is also a stress-inducing component afterwards. Except for one competitor, the control component was judged to be smaller afterwards than before. The enjoyment component for the first race was smaller for almost all competitors afterwards. The tension and stressors are almost always greater after the competition than before, regardless of the result achieved.

Comparison of the psychological questionnaire (affective anxiety) and effectiveness (based on rankings), (rankings achieved in races F1-F2)

From all the tested competitors, we selected those who started and finished the race in both races, thus achieving a valid ranking. Nearly forty competitors take part in each race. Among those placed, we classified those who achieved one of the first six places as successful, and those who reached the finish line above that were classified as less successful. Based on the above, we compared the physiological, locomotor and mechanical characteristics of the two groups. A significant difference was found in the maximum speed (M(e)=79.4± 7.6 - M(ke)=65.1±3.08), p=0.013 in the average speed (M(e)=38.2±1.7 - M(ke)= 33 ,8±1.5); p=0.008 and the sprint averages (M(e)=219.5±5.0 - M(ke)= 194.0±5.6); between p<0.000, in favor of the more successful group (Table 16). In the second race, between the sprint averages (M(e)=224.7±6.6 - M(ke)= 195.0±9.09); p=0.002.

ANSWERS TO THE HYPOTHESES

H1. Our first assumption was partially confirmed, since the body type of the competitors we examined is "endomorphic - mesomorphic". In this body type, II. component is dominant, but component I is greater than component III. It is true that the difference between the two body type variants is minimal, but the dominance of the second component can be interesting from the point of view of body composition.

H2. The above-mentioned body type can represent a chance in terms of optimal body composition. The presented anthropometric data show that the lean body mass (LBM) of the internationally registered competitors is significantly higher than that of their contemporaries who are successful in the domestic field, so our assumption proved to be true.

H3. In the third hypothesis, we assumed that the lower extremity (approach-extractor) muscles of the examined adolescent competitors - regardless of their grouping - respond symmetrically to the effect of a single load. Also, the relationship is significant in the lower and upper limb functioning of internationally registered competitors. The first half of our assumption was fully confirmed, as the responses to the single load were symmetrical in both groups and the relationships in the first group were deterministic and positive. The second half of the assumption was also proven with the addition that the connection between the functioning of the lower and upper limbs of the competitors registered in the domestic field is non-existent or of lesser strength.

H4. In motocross, the heart rate is usually greater than 80% of the theoretical heart rate and is kept at a fairly high level for the duration of the race. We assumed that the maximum heart rate measured in the laboratory is reached by the competitor in several cases, either during free training or during "sharp" races. In the age group Hungarian motocross championship that we followed, the competitors spent <15 minutes in the 90-100% intensity zone during the ~20-minute race. So this assumption of ours has been fully confirmed.

H5. During the test until complete exhaustion in the exercise physiology laboratory, we found aerobic and anaerobic phases of alternating duration. Heart rate recorded during competitions
based on the patterns, we found that they cross the anaerobic threshold almost every night and stay there with an alternating pattern. We hypothesized that the metabolic background of the two groups is different, that is, the respiratory coefficient (RER=VCO2/VO2) of the internationally registered competitors is significantly higher than that of their contemporaries registered in the domestic field. This assumption was not confirmed, as the averages of the metabolic quotients of the two groups did not differ from each other.

H6. The rest time between the first and second races is barely two hours. The averages of the regeneration time per group are much higher than this, even 2 times this. We hypothesized that the time spent in the intensity zones would shift in favour of the lower zones in the second run. Our assumption was confirmed, since out of the two critical intensity zones (4, 5) the competitors spent much longer in 4 than in 5.

H7. The central premise of the (IZOF) model is that each athlete has an individually pre-optimal bandwidth (zone/range) of stress intensity within which best performance is most likely. We assumed that the aforementioned bandwidth is narrower for those competitors who performed more effectively (achieved a better position) during the races. Our assumption was partially confirmed and is more true for the second race than for the first. In particular, the control of pre-competition anxiety of different intensity (depending on the phase and period/season of the competition) and self-confidence (also regarding the intensity of pre-competition anxiety) and self-confidence (also related to the risks of the sport) are considered essential in a high-speed sport where the mistake can cause serious injury to the athlete or have consequences for his career (Crundall et al., 2013; Dosil, 2005, DeMojà C. & DeMojà, G., 1986).

H8. We assumed that at the same time, the heart rate pattern also changes with the speed, i.e. during or after the highest speed section of the track, the athletes' heart rate also increases/decreases as a result of external and internal forces acting on them of alternating strength. At the beginning of the race, the heart rate is 68% of the total load. After the start (one and a half minutes), the heart rate is 97% of the total load and this value decreases or increases by only a few percent. The speed is the highest in the long straight section of the track, while it can be reduced by almost half in the bends and uphills. Increases and decreases in speed are not accompanied by significant fluctuations in heart rate. The degree of fluctuation varies between 5-8 beats×min-1. Our assumption formulated in hypothesis number eight does not hold up, we rejected it.

CONCLUSIONS

The doctoral dissertation tries to convey results to professionals that can make motocross competitors and their coaches more effective in domestic and international competitions. Knowing the results, it is obvious that further research work and the development of evidence-based methods are needed to develop high-quality training for athletes, which can improve their performance in competitions. There is no doubt that, due to the nature of the sport, future research should strive for the frequency of longitudinal physiological, psychological and biomechanical tests in addition to transversal. In order to gain a deeper understanding of the results, the magnitude of the metabolic, mental, technical and muscular system effects, as well as the magnitude of the stress associated with the anthropometric characteristics, should also be examined during subsequent research. The influence of the human component on final performance is currently a less studied area, so in order to improve competition performance, this must also be taken into account.

NEW RESULTS

1. In the age group Hungarian motocross championship we followed, the competitors spent <15 minutes in the 90-100% intensity zone during the ~20-minute race. It is important to add that this intensity zone is the section near the respiratory compensation point (RCP) and the peak of the load (~Peak HR). This load pattern is a new element of the dissertation, specifically because it helps the preparation team in the load planning of the competitions.
2. The central premise of the (IZOF) model is that each athlete has an individually pre-optimal performance bandwidth (zone/range) in anxiety intensity, within which the best performance is most likely. We recognized this psychological evidence and were able to identify competitors on the basis of their effectiveness/ineffectiveness and affective anxiety levels.

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