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Comparison of Metabolic Load in Paralympic and Olympic Athletes in Elite Dressage Sports and Need to Tailor Make the Sport Specific Training

Stolz I[1*], Wittschier R[1], Grebe, R[2], Fercher C[3], Augustijn J[3], Krychowski S[2], Abel T[1]

[1]Institute of Movement and Neurosciences, German Sport University Cologne, 50933 Cologne, Germany

[2]German Disabled Sports Federation, Tulpenweg 2-4, 50226 Frechen,

[3]Germany Olympic Training Centre Warendorf, Dr.-Rau-Allee 32, 48231 Warendorf, Germany

***Corresponding author:** Stolz I, Institute of Movement and Neurosciences, German Sport University Cologne, 50933 Cologne, Germany.

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Abstract

In performance-oriented dressage, in addition to the horse's capability, the rider's physical performance and athletic capacity have a significant influence on the outcome of a competition. For para dressage athletes, in this regard the sport-specific performance loads, including health-related factors, play a special role due to divergent medical backgrounds. To investigate sport-specific performance load on the athlete in para dressage, 10 elite athletes with German national team status completed a standardized training protocol in this study. Their sport-specific metabolic load was afterwards compared to 3 athletes on a similar performance level from Olympic sports, which completed the same protocol. Performance loads were examined via a comprehensive diagnostic including metabolic parameters (heart rate, blood-lactate) and subjective exertion (RPE) for the total of athletes (N=13). Results provide first insights into metabolic load in elite para dressage against the background of the heterogeneity of athletes' capacity. In some athletes, obtained data also shows differences between objective and subjectively perceived strain (HR and RPE). Both, Paralympic and Olympic riders show a significant increase of strain and exertion over five measurement time points during a standardized training session with regard to blood lactate and RPE. The study confirms findings of previous studies in Olympic sports, that metabolic strain rises strongly with increasing loads and ridden gaits in dressage riding also for the Paralympic athletes. The data obtained contributes to generate further understanding in capabilities and limitations and thus to expand performance development of the toplevel Paralympic training and support system in Germany.

Keywords: Exercise Physiology; Performance Diagnostics; Physical Fitness; Rider Fitness; Sports Medicine;

Introduction

In high performance dressage, as in other competitive sports, physical and mental performance capability play an important role for a successful outcome of a competition. Here, the sport-specific requirement profile includes different performance-relevant factors, as a fine interplay between rider and horse and harmonious interaction of movements, which are key factors for a successful competition ride. In the Olympic field, few studies can be found concerning this topic [1, 2]. Studies primarily assessed the performance of horses or the fit of the rider-horse duo in relation to athletic success and have been able to generate key insights for competitive performance [3-5]. For a successful ride, also the riders condition, mobility and coordination skills are important riding requirements and performance-determining factors [6]. In this context, Uldahl et al. have shown correlations between the pelvic mobility and balance of riders on a gymnastic ball and increased riding abilities [7]. Specifically, increased pelvic control and mobility were found to be predictive of equestrian ability and equestrian harmony in athletes [7]. A study by Mason et al. showed an increased lumbar spine loading during faster pace dressage riding [8]. They also note, that riders needs to activate their core and be flexible at the hips to reduce the lumbar load, to avoid being unbalanced at each diagonal stride [8].

Douglas et al. discussed in their systematic review, if strength ability, reaction time, balance ability, and endurance ability were dominant components of sport-specific performance in equestrian athletes [1]. The authors concluded, that, based on the paucity of existing physiological and biomechanical data on equestrian athletes, the demands of the sport must be better understood firstly in order to adequately implement the development of evidence-based sport-specific and potentially performance-enhancing strength and conditioning programs [1]. Furthermore, past research indicated, that exercise load is depending on the discipline and gait ridden and should be regarded more discipline-specific in equestrian sports [1, 9].

Based on the findings of Olympic athletes, correlations between higher physical fitness levels and increased riding performance may also be derived for para dressage [9, 10]. However, there is currently little scientific data regarding the exercise induced load and performance strain of Paralympic dressage athletes, so that the overall understanding is rather limited. Paralympic athletes differ from Olympic athletes in that they must have a classifiable disability according to the Fédération Equestre Internationale (FEI) standards [11]. Classifiable athletes are divided into five para dressage competition classes (Grades I – V), which correspond to the nature and extent of classified impairments. In this regard, Grade I represents the class of athletes with the highest functional impairments, Grade V represents the class of athletes with the least functional impairments [12].Class allocations are based on a dressage-related functional classification system taking medical status of athletes into account. Thereby, athletes with different impairments but similar functional capabilities in regard to dressage riding, complete the same competition tasks within their classes in competitions. Competition tasks for each class are standardized in international competitions according to FEI [11].

Against the background of the heterogeneity of athletes in the different competition classes in para dressage, a comprehensive approach, considering the psycho-physical conditions of athletes, is thereby required. In this regard, the aim of the study was to investigate the metabolic load in elite para dressage in comparison with athletes on a similar performance level in Olympic sports via an explorative, cross-sectional approach. Thus, initial discipline-specific insights into the metabolic stress of top Paralympic athletes under field conditions can be provided.

Materials and Methods

The present study examines the sport-specific load of para dressage riding by means of a cross-sectional investigation including 10 Paralympic riders (Grade II – V, 9 females, 1 male) with German National Paralympic team-status compared to data of 3 Olympic riders on a similar performance level (all female). The research question aimed to elicit which metabolic loads are present for athletes with disabilities and chronic conditions in the sport of para dressage (primary endpoint). A comprehensive performance diagnostic was carried out during a standardized 40-minute training session with the Co-National Coach at the begin of the competition season 2022 (see standardized protocol in Table 1 in Appendix). All included athletes participated on their competition horses. In this standardized training session, data was collected at five measurement points: The first measurement point was a resting value immediately before training began (MTP1). The second value was taken immediately after the warm-up phase on the horse (MTP2), the third at the end of the intensive main exercise phase (MTP3), the fourth immediately after completing an official FEI competition task of the respective rider's level (MTP4) and the fifth as a recovery value directly after the end of the training after the completion of 40 minutes training (MTP5). The recorded training session was not a graded exercise test with a stepwise progression in the test protocol but rather a standardized training diagnostic to determine the strain within the typical phases of a youth squad training program for the Paralympic athletes.

Since the underlying conditions and disorders of the athletes varied, the metabolic loads of athletes were investigated individually against the background of selected parameters and their influence on performance. All underlying disabilities with a linkage to the competition class are shown in Table 2 in Appendix.

Metabolic aspects were carried out by measuring heart rate (HR) with a HR watch and associated chest strap (Polar M200 model 2F). The HR was read out by the watch display at the measurement times and the saved training summaries. Blood lactate samples were collected from the earlobe and analyzed using an enzymatic-amperometric sensor chip system (Biosen C-line EKF-diagnostic GmbH, Barleben, Germany). Subjective exertion was captured by using the Borg RPE Scale (Rate of perceived exertion, range six "no exertion" to 20 "maximal exertion") during the standardized 40-minute dressage training period (see standardized protocol, Table 1 in Appendix). The scale between 6 and 20 was selected to reflect HR analogous to multiplication by a factor of ten [13].

Generated data was analyzed using IBM SPSS 28. Mean values (M) and standard deviations (SD) were calculated for the total group of athletes to help identify outliers in both positive and negative directions. To analyze group and age effects in regard to training load, oneway ANCOVA with repeated measurements was carried out. Hereby, tests on intermediate subject effects were calculated to estimate relative differences of both groups to each other. Since multivariate normal distribution was not given within the small sample size and unequal group sizes, box test for equality of covariance matrices could not be calculated. Results can only be interpreted cautious and provide initial indications for metabolic strain in elite para dressage. Mauchly-test on Sphericity was carried out to determine whether the error covariance matrix of the orthonormalized transformed dependent variable is proportional to the unit matrix. When p-value of Mauchly-test on Sphericity were not significant, Huynh-Feldt (HF) was applied to determine internal subject effects. Profile plots of the estimated marginal means were output to indicate differences over time. Data collection was conducted by experienced sports scientists according to standardized procedure regulations. Athletes gave written informed consent and were educated about all aspects of the investigation (for persons under the age of 18, this included the additional consent of parents or legal guardians). The study was approved by the Ethics Committee of the German Sport University Cologne and in accordance with the 1964 Helsinki Declaration and its later amendments (ethical approval code 051-2022).

Results

The study group of Paralympic dressage athletes consisted of nine women and one man with an average age of 36.2 years (SD=15.89). The large standard deviation is due, among other things, to the wide age range between the oldest (59-year-old) and youngest (17-year-old) subjects. In terms of body mass index (BMI) as an indicator of normal or overweight, the group showed a mean value of 19.58 (SD=2.3). Most of the riders compete in the fifth Grade (n=4), which classifies them as athletes with maximum dressage related functioning status, all other Grades were represented with two athletes each. Only Grade I remained unrepresented (see underlying disabilities and related grades in table 2 in Appendix). The study group of athletes from Olympic sport were selected in order to be comparable and contained an average age of 34.3, (SD=11.85), also with a wide range (youngest 27-year-old, oldest 48-year-old) and BMI mean value of 19.63 (SD=.78).

The following table (Table 1) shows mean values of lactate, HR and RPE performance curves of all included athletes. Defined lactate concentrations of 2 and 4 mmol/L, which characterizes the metabolism transition from the primarily aerobic range to an increasingly anaerobic range, was reached after MTP2 (warm up) during the standardized training test in the total sample of athletes.

	Paralympic dressage riders, (n=10)						**Olympic dressage riders, (n=3)**					
MTP	**HR**		**Lactate**		**RPE**		**HR**		**Lactate**		**RPE**	
	M	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**	**M**	**SD**
MTP1	86.1	14.2	1.3	0.4	8.1	2	97.3	24.4	1.7	0.1	6	.0
MTP2	132.9	13.8	2.8	1	12.9	1.5	142	30.5	4.2	1	6	2.1
MTP3	145.1	14.5	3.7	1.9	14.1	1.7	164.7	26.8	7.1	2.5	13.3	1.7
MTP4	149	15.3	4.3	2.7	15	2.3	171.3	27.9	7.7	3.1	13.3	1.2
MTP5	102.9	12.6	2.9	12.6	9.9	2.3	123.7	28	4.5	2.1	8	2.2
HRmax	171.1	11.6					179	24.1				
HR ⌀	128.4	8.5					143	23.8				

RPE value of athlete ID 01 and HRmax and HR⌀ of athlete ID 03 could not be collected due to technical reasons. ID01 and ID03 were each not included in the calculations of means of RPE, HRmax and HR⌀

MTP = (measurement timepoint)

Table 1: Mean values training load during the standardized training session.

The highest individual lactate value was 10.76 mmol/L in paralympic athlete ID 06 at MTP4 directly after riding a dressage competition specific task during the training session. Also, higher lactate values were measured in ID 03 and ID 04 at the same measurement time point 4 with values of 5.63 (ID 03) and 7.08 (ID 04). Underlying physical disabilities of the athletes were hereditary spastic spinal paralysis (HSP) in ID 06, pelvis and ancle joint fracture in ID 03 and hip dysplasia with paralysis resulting from nervous femoralis impairment in ID 04. There is currently no existing evidence, that these disabilities influence the maximum heart rate, lactate characteristics and subjective feeling of exertion in an exceptional way.

The remaining five athletes showed an increased lactate concentration in the aerobic range, that remained under 4 mmol/L. All athletes showed a significant increase in blood lactate during training and a decrease after completion (see Table 2). The slightest increases of lactate concentration were measured in ID 02 and ID 05, which both had their lactate concentration peak earlier during the 40-minute training with values of 2.04 of ID 05 in MTP2 (after the warm up) and 2.21 in MTP3 (after 30 minutes of training right before the competition specific task) (see Table 1).

The HRmax with respect to the total duration of 40 minutes of training averaged 171 beats per minute (bpm) (SD=12.26) for the total of Paralympic athletes. The highest single measured HRmax was 186 bpm. HRmax of Olympic athletes was 179 bpm, with a single measured maximum of 197 bmp. The average HR of Paralympic athletes was 128 bpm, the average HRs of Olympic athletes was 143 bpm. The RPE score ratings showed that most athletes subjectively perceived training in the final loading stages of the protocol as "very hard". The maximum rated value was 17 ("very hard") for four out of nine Paralympic athletes, partly reflected by the higher HRmax (M=171). In regard to RPE, figure 1 shows a profile plot of the estimated marginal means to indicate differences of RPE within the two groups over time. As Table 1 shows, Olympic athletes show similar metabolic responses to the Paralympic athletes (rise of HR and blood lactate) in the same protocol stages, but perceive training subjectively less hard (see Figure 1).

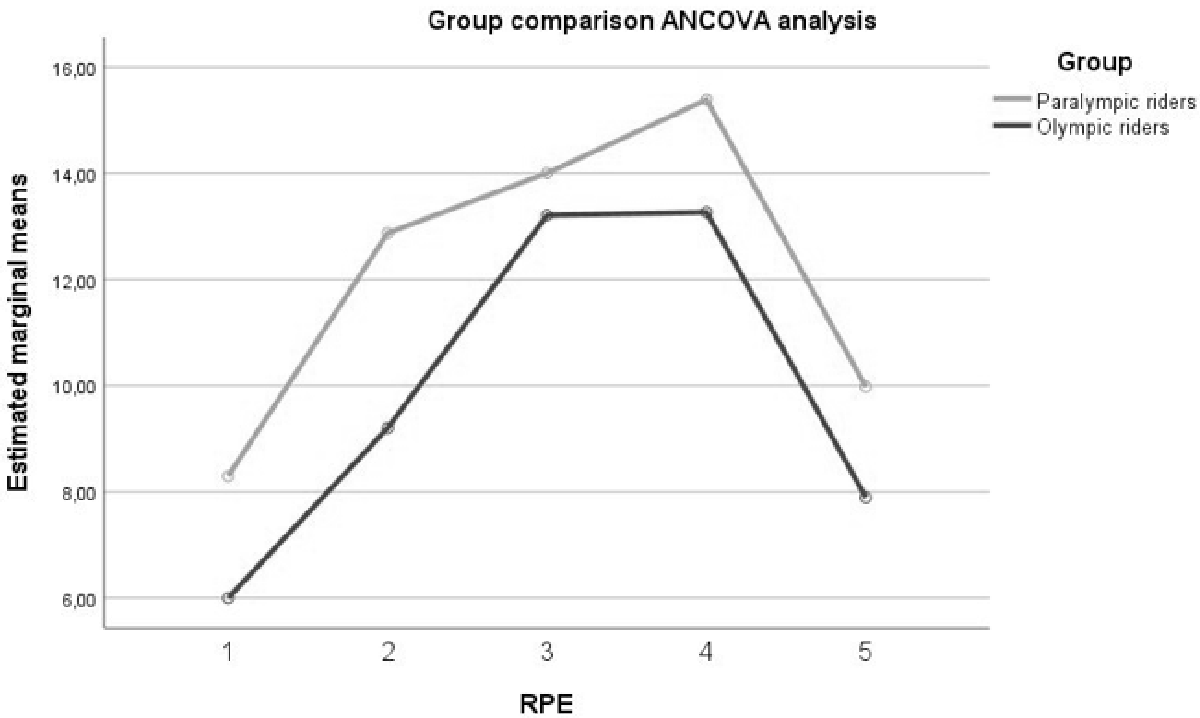

Figure 1: Estimated marginal means for rating of perceived exertion (RPE).

ID 11 showed an average HR of 165 bpm during the 40 minutes of training, with a HRmax of 197 bpm. ID 12 showed an average HR of 110 bpm during training and a HRmax of 145 bpm. ID 13 showed an average HR of 154 bpm during the training session, with a HRmax of 195 bpm.

In some athletes, RPE displays a larger difference to their HR: For example, ID 06 (age 19) perceived MTP1 (preliminary measurement at rest) with a HR of 77 bmp as 7 -"extremely light". At MTP2 after the warm up, with a HR of 124 bpm, he perceived training as 13 - "somewhat hard". MTP3 and MTP4 before and after the completion of a competition specific task were both perceived as 17 - "very hard" with HRs of 129 bpm (MTP3) and 143 bpm (MTP4). MTP5 after the cool down phase was perceived 8 – "very light" with a HR of 115 bpm. ID 07 (age 56) perceived MTP 1 with a HR of 74 bmp as 11 -"fairly light". At MTP2 after the warm up, training was perceived 15 - "hard" with a HR of 141 bpm. Both, MTP3 and MTP4 before and after the completion of a competition specific task, were perceived as 16 – "hard" and 17 – "very hard" with HRs of 127 bpm (MTP3) and 149 bpm (MTP4). At MTP5, after the cool down, with a HR of 104 bpm, training was perceived 15 – "hard". Only one athlete's RPE (ID 01) could not be collected due to situation-related circumstances.

As table 2 shows, effect sizes of lactate and RPE were strong for the total of athletes in regard to measurement timepoints according to Cohen (1988) [14]. Lactate and RPE differed significantly in regard to the different measurement timepoints (lactate $F(4.36)=4.480$, $p=.005$, partial $\eta^2=.332$, RPE $F(4.28)=5.900$, $p<.001$ partial $\eta^2=.457$).

Effect	Typ III square sum	df	mean squares	p	partial η²	F
Lactate	37.4	4	9.35	.005	.332	.7
Lactate*group	20.01	4	5	.068	.21	
Lactate*age	10.33	4	2.58	.313	.121	
HR	3138.81	4	3.81	.011	.297	.65
HR*group	217.55	4	54.39	.899	.029	
HR*age	111.95	4	27.99	.968	.015	
RPE	58.35	4	14.59	.001	.457	.92
RPE*group	5.03	4	1.26	.73	.068	
RPE*age	8.17	4	2.04	.826	.52	

Table 2: Effect sizes of MTP on metabolic load and RPE (N=13).

As table 2 indicates, ANCOVA with repeated measurements did not show significant differences between the groups of Paralympic and Olympic athletes, nor age related differences in metabolic strain in regard to increased physical load.

Discussion

The data obtained contributes to providing initial insights into the sport-specific load profile of para dressage and serve as an initial assessment of the elite performance level current status in Germany. Due to the sport-specific profile of para dressage as a moderate-intensively long-term performance load, the aerobic metabolism of basal endurance is particularly required in Paralympic and Olympic dressage riding [15]. The results show that group affiliation was not an affecting variable in regard to physical strain over increased training load. All athletes showed a significant increase in metabolic strain over increased training load during measurement time points with faster gaits ridden, that dissolved again at the end of the dressage session with the cool down phase.

Advantages of a sufficient endurance in regard to competition represent a more effortless and longer performance ability with a more economic and quicker recovery, that may also contribute to psycho-physical performance capacity including for example concentration and response capacity, that can be maintained longer or quicker [16]. Judgement in Olympic dressage competitive performance is highly focused on correct riding, line placement, rider-horse interaction and the key-elements of rhythm, suppleness, connection, impulsion, straightness, collection and thoroughness [17]. These requirements in the execution of the demanded elements do not differ in Para dressage competition, it is only differentiated in less or more complex lessons and the ridden gait. Paralympic athletes may also have to compensate for muscular imbalances in their movement with the horse, for example due to missing limbs or the reduced controllability of muscle tension of their extremities. Therefore, the included Paralympic athletes would benefit from supplementary athletic training, especially those whose subjective load was considerably higher than the objective load during the recorded training session. This may contribute to them experiencing less strain during hard training phases.

In recent years, there has been a decline in the basic athletic fitness of young riders in Germany, which was shown in a study conducted by Becker (2018) for Olympic athletes at the same age as the majority of the included Paralympic dressage athletes (N=100) [18]. For Paralympic athletes no published data in regard to athletic fitness could be found yet. Further, below-average endurance and strength performance abilities were also demonstrated in Olympic riders in the study of Huppertzl and Ludewig (2003) [15]. Only in terms of coordination they showed above-average values in the areas of reaction and balance ability compared to the normal population [15]. In this context, Hyttinen and Häkkinen noted, that female equestrians in Finland (n=52) had lower VO2max values as an indicator of endurance performance compared to non-athletic women of the same age and would benefit from additional strength training [19].

In agreement with Huppertzl and Ludewig (2003), the present study showed that half of the included Paralympic and Olympic athletes, presumably more endurance-trained riders, had to expend less aerobic capacity to meet the demands of their discipline, while others with lactate concentrations of 4 mmol/L and higher were physiologically under greater strain completing a comparable training [15]. In athletes with higher HR and lactate concentrations, underlying disabilities and medical conditions are a factor that should be examined and monitored more intensively in future research and observed through a fine lens. Furthermore, individualized training programs, that allow Paralympic athletes to maintain a predominantly aerobic energy supply even during longer periods of moderate intensity exertion, should be created using endurance-oriented sessions. Included Olympic athletes, that showed a varying physical strain within the 40-minute training exercise would presumably also benefit from endurance-based supplementary training. Overall, the gained data are in accordance with past investigations regarding higher measured HR of athletes in relation to the gait ridden, independently of the equestrian performance level [20].

Additionally, the sport-specific training load should be examined in future investigations in more detail in a prospective pre-post study design. In this context, the extent to which the individual performance of the riders can be optimized by specific training recommendations with regard to a long-term increase in para dressage performance should be specifically investigated, including effects on competition performance. Furthermore, the effectiveness of dressage-related supplementary athletic training is to be examined on the basis of a subsequent outcome measurement and against the background of athletes individual biopsychosocial functioning levels. To determine physical load during dressage riding and athletic capability of elite para dressage athletes, it is only to a limited extent possible to fall back on scientific studies (which exist in small numbers anyway) on training documentation in Olympic dressage sport or leisure sport athletes. In order to elicit knowledge about possibilities and limitations of performance development and thus to expand the professionalization in the toplevel Paralympic support system, more knowledge about trainings load and athletic capability of para dressage athletes is to be evolved.

Against the background of the explorative study approach, there are several limitations to address. The included elite dressage athletes overall showed differences in age, experience, grade and severity of medical condition. The sample size of 10 para dressage athletes and 3 Olympic athletes was small and could only allow to draw first conclusions about the sport-specific training load profile of elite para dressage. Nevertheless, the number of high-performance para dressage riders in Germany is also limited, yet there are no official numbers that could allow representativeness. The standardized protocol can only show the sport-specific load in a limited comparable way due to influences of different horses, gaits and physiological-morphological rider-horse fits. The approach of measuring the performance load in para dressage sports itself has proven to be useful in order to draw conclusions about specific physical load in regard to performance capacity of included athletes. Past medical examinations of riders in terms of HR and lactate measurements used bicycle ergometer or treadmill during standardized laboratory tests [19]. These experimental setups seem to make the physical load adequately measurable but it remains exceedingly difficult to conclude from the isolated assessment of endurance performance in another activity on the athlete's dressage-specific performance capability, especially in consideration of horse's movement quality and simultaneous movement interactions [21].

Conclusions

The gained data provides first insights in elite Paralympic dressage metabolic load compared to Olympic athletes and supports the necessity to reflect on how to enhance the athletes` physical capabilities more targeted with regard to their sport specific demands. Subjective and objective training strains were comparatively high in some athletes, specific causal relations cannot be drawn based on the cross-sectional study design. Furthermore, for athletes who were subjectively under a lot of stress and felt that the training was predominantly "hard", but whose objective data did not reflect it to this extent, consideration should be given to how objective strain can be perceived more accurately or which additional stressors make the training subjectively "hard".

The demonstrated rising physiological load at defined test-conditions indicates the potential for a positive influence of non-riding-based endurance training to reduce the demands of competition for para dressage athletes and thus may lead to a higher level of performance. Against the background of sport specific key-movements and functional riding skills, a general, targeted endurance and strength-related supplementary training could probably also have a positive effect on competition and training performance of the total of included athletes, that have shown higher exertion rates during the training session. Targeted interventions could be applied to consider how these athletes' tolerance to exertion can be improved. For example, through supplementary strength or endurance training, which increases the overall fitness and also has the potential to increase recovery capacity. Plus, physiological peculiarities based on underlying diseases and medications on metabolism should be recorded in more depth in a medical anamnesis and addressed in future analyses.

The gained data contributes to a targeted subsequently long-term performance development on the basis of comprehensive diagnostics and profiling of training load in para dressage sports, considering the specifics of the sport. Further knowledge in order to increase sport-specific performance based on an individualized supplementary training of endurance and athletic capabilities should be gained via further research including dressage athletes from Olympic and Paralympic sports.

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Ethical Considerations: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethics Committee of German Sport University Cologne (protocol code 051-2022). Written informed consent was obtained from all subjects involved in the study.

Conflicts of Interest: The authors declare no conflicts of interest.

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Author Contributions: Conceptualization and methodology, Isabel Stolz and Thomas Abel.; Data acquisition and processing, Isabel Stolz, Rachel Wittschier and Thomas Abel (Paralympic riders), Isabel Stolz, Julia Augustijn, Christina Fercher (Olympic riders); Project administration and organization of the measurements, Rolf Grebe and Simone Krychowski. All authors have read and agreed to the published version of the manuscript.

Appendix: Additional Tables

Duration test: 40 minutes training time	
1. lactate, heart rate and Borg (RPE) value at rest before the start of the training session	0 minutes (before),
	not on the horse
2. lactate, heart rate and Borg (RPE) value	After 10 minutes on the horse (walk, trot) [warm up]
3. lactate, heart rate and Borg (RPE) value	After a further 20 minutes/ 30 minutes in total (1st load level), immediately before riding a competition dressage task, on the horse
4. lactate, heart rate and Borg (RPE) value	Immediately after riding a competition dressage task (2nd load level), on the horse
5. lactate, heart rate and Borg (RPE) value after the completion of the training session	After 40 minutes (end of the training session), not on the horse [after cool down]

Table 1: Standardized training protocol.

Grade	**N=10)**	**Any present or underlying disability(ies)**
I	-	
II	n=2	ID 09 Spina bifida ID 10 Spastic cerebral palsy/diplegia,
III	n=2	ID 07 Incomplete paraplegia (C4), high tetra paresis and severe scoliosis (55 degrees) ID 08 Severe craniocerebral trauma due to cerebral hemorrhage after fall
IV	n=2	ID 01 Impaired spatial vision and physical motor skills, mental disability due to meningitis after birth ID 06 Hereditary spastic spinal paralysis
V	n=4	ID 02 Traumatic right transfemoral amputation and failure to close a heart valve ID 03 Triple ankle fracture right left and double pelvic fracture right ID 04 Hip dysplasia on the left and femoralis palsy ID 05 Traumatic right transtibial amputation and metal clavicle reconstruction
Athletes ID 11 – ID 13: Olympic riders without underlying chronic diseases or disabilities		

Table 2: Grades and disabilities of Paralympic athletes.

References

1. Douglas JL, Price M, Peters DM (2012) A systematic review of physical fitness, physiological demands and biomechanical performance in equestrian athletes. Comparative Exercise Physiology 8:53–62.
2. Wilkins CA, Wheat JS, Protheroe L, Nankervis K, Draper SB (2022) Coordination variability reveals the features of the 'independent seat' in competitive dressage riders. Sports Biomech :1-16.
3. Bojer M (2010) Modern Sporthorse Training. pferde spiegel 13:124-128.
4. Clayton HM, Hobbs SJ (2017) The role of biomechanical analysis of horse and rider in equitation science. Applied Animal Behaviour Science 190:123–132.
5. Twele L (2019) Performance diagnostics under field conditions – Parameters, practical application and interpretation of results. pferde Spiegel 22:155–163.
6. German Olympic Equestrian Committee (2018). Sport motor test for riders. FN Publishing.
7. Uldahl M, Christensen JW, Clayton HM (2021) Relationships between the Rider's Pelvic Mobility and Balance on a Gymnastic Ball with Equestrian Skills and Effects on Horse Welfare. Animals (Basel) 11:453.
8. Mason C, Greig M (2020) Lumbar Spine Loading During Dressage Riding. J Sport Rehabil 29:315-319.
9. Chmiel C (2006) The rider with a high level of condition. More safety and sense of feeling. Warendorf, FN Publishing.
10. Bye T, Chadwick G (2018) Physical fitness habits and perceptions of equestrian riders. Comparative Exercise Physiology 14 :183–188.
11. Fédération Equestre Internationale. Para Dressage Tests (2023).
12. International Paralympic Committee. Classification (2024).
13. Borg GAV (1962) Physical Performance and Perceived Exertion.
14. Cohen J (1988) Statistical Power Analysis for the Behavioral Sciences.
15. Huppertzl C & Ludewig I (2003) Is Equestrian Sport "Sports"? Rider-Revue International 26: 26-27.
16. Otte-Habenicht M (2014) The riding badge 5-1 of the German Equestrian Federation. Well prepared for the test. Warendorf: FN Publishing.
17. Schütte R & Riedel M (2013). Dressage riding with a handicap in competitive sport. Basic structures and developments. MuP 5: 174.
18. Becker O (2018) From Rider to Athlete.; FN Publishing: Warendorf.
19. Hyttinen AM, Häkkinen K (2019) Physical fitness profile in female horseback riders. J Sports Med Phys Fitness 59:1944-1950.
20. Bojer, M., Lötzerich, H. (2000a). Investigations of the heart rate at different load in equestrian sports. Moving in water - more than just swimming. Symposium. K., Daniel (Ed.).
21. Sevenich S, Fercher C (2020) Performance diagnostics in equestrian sport - a determination of the status quo. Sports Orthopaedics and Traumatology 36:326–334.