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An investigation into the association of the physical fitness of equestrians and their riding performance: a cross-sectional study

A.M. Aegerter[1*], S.N. Latif[2], M.A. Weishaupt[2], B.E. Gubler[1], F.M. Rast[1], A. Klose[3], C.A. Pauli[1], A. Meichtry[1] and C.M. Bauer[1]

[1]Institute of Physiotherapy, School of Health Professions, Zurich University of Applied Sciences, Technikumstrasse 71, 8400 Winterthur, Switzerland; [2]Equine Department, Vetsuisse Faculty, University of Zurich, 8057 Zurich, Switzerland; [3]University of Münster, Institute of Sport and Exercise Sciences, Horstmarer Landweg 62b, 48149 Münster, Germany; andrea.aegerter@zhaw.ch

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RESEARCH ARTICLE

Abstract

Poor riding performance may be due to medical issues with the horse or a variety of other factors, such as inadequate equipment or deficiencies in training. The physical fitness of the equestrian is one of the most unexplained factors of current research. The aim of this study is to investigate the association between the physical fitness of the equestrian and riding performance. 115 equestrians were assessed for physical fitness and riding performance. Seven components of physical fitness (balance, endurance, flexibility, reaction, speed, strength, symmetry) were measured by a physiotherapist using equestrian-specific tests. Based on a video-recorded riding test, individual riding performance was rated by two equestrian judges. The riding test included the horse and rider performing a walk, sitting trot, rising trot and canter in both directions. A linear model for riding performance, including the domains of physical fitness and potential confounders (body-mass-index, riding experience, hours of riding per week, and test-motivation), was fitted to the data. Inter-rater reliability of the judges was investigated by calculating the intraclass correlation coefficient (ICC). Endurance, reaction and strength were positively associated with riding performance, whereas flexibility had a negative association. The final model could explain 16.7% of the variance in riding performance. The effects of endurance and strength were significant ($P<0.05$), but not that of reaction. No association with riding performance was found for the components of balance, speed and symmetry. The inter-rater reliability of judges was confirmed to be 'good' to 'excellent' (ICC=0.9, 95% confidence interval: 0.86-0.93). Findings suggest that physical fitness is positively associated with riding performance. Fitness-training for equestrians should be included in current training concepts. Future research should investigate whether similar associations exist for junior and elite athletes.

Keywords: horse, equestrian, equine, sports, regression

1. Introduction

2% of the Swiss population are occasional equestrians (Bianchi, 2014). Poor riding performance (RP) is often a result of the horse's health condition (Zimmerman *et al.*, 2012). Additional factors, such as poor saddle fit and deficiencies in schooling and training of the horse or equestrian, may reduce RP. However, the most neglected factor in current research is the equestrian himself/herself (Greve and Dyson, 2013).

The ability to ride requires not only practice and sensitivity to the horse's movement, but also physical fitness (PF) (Greve and Dyson, 2013). The two components of PF that have received the most attention over the past decades are flexibility and symmetry, since these are considered very important for RP (Gandy *et al.*, 2014; Hobbs *et al.*, 2014; Symes and Ellis, 2009). Flexibility is regarded as a precondition for a supple seat, whereas the equestrian's symmetry is important both for the stability of the horse and equestrian. Both lead to better harmony and RP (Gandy *et al.*, 2014; Heipertz-Hengst, 2002; Meyners and Putz, 1992). In contrast, the PF components of balance, endurance, reaction, speed and strength, which are considered equally important, have received little attention to date (Notz, 1999; Weineck, 2007).

To quantify the PF of the equestrian, a sport-specific test has been created by the German Olympic Committee for Equestrian Sport (Koch *et al.*, 2012). This test includes twelve tasks to examine the equestrian's motor skills. Unfortunately, the test was designed for juniors, certain elements are not specific to horse riding, and symmetry aspects are not considered. Therefore, a revision of the existing sport-specific test was considered necessary. This was realised prior to data collection through expert interviews and focus group discussions. To address the limitations discussed, the new test was created for riders over the age of 18 and assessments of symmetry and balance were included.

So far, no study has quantitatively investigated the association of PF on RP and it is still unclear which components of PF are the most important in horse riding. The results of this study could help to elucidate the predictive validity of a sport-specific test for success at the elite level (Swiss Federal Office of Sport, 2017; Swiss Olympic Association, 2008).

From a physiotherapeutic point of view, the findings could be used to foster equestrian sport among young people and create an addition to current training concepts. The reputation of physiotherapy in the treatment of equestrian-specific issues may be strengthened and an interdisciplinary approach to riding training may be realised. The outcome could expand the variety of special fields and topics for the physiotherapy profession. Therefore, the aim of this study is to assess the association of PF and its components on RP. It is hypothesised that a higher PF will lead to better RP.

2. Materials and methods

Setting and study design

The study design is cross-sectional (Seo *et al.*, 2016). This study is a sub-study of the 'Back health of the Swiss riding horse population – a survey study' (ARAMIS-No. 2.16.10) which was conducted from June to November 2017 at five different locations in the German and French-speaking parts of Switzerland. This main study explores the influence of various factors, such as the equestrians' physical fitness, on the back health of riding horses. The experimental protocol was approved by the Animal Health and Welfare Commission and the Ethical Commission of the Canton of Zurich, Switzerland (TVB-Nr. ZH003/17-28698; BASEC-Nr. 2017-00188). All participants gave written informed consent prior to the study.

Participants

In total 420 equestrians stated their interest after the study was announced through the official journal of the Swiss Equestrian Federation. Of those 340 (80.9%) signed a declaration of consent after receiving the participant information and 244 were randomly selected and scheduled for an appointment. Of those, a subsample of 120 Swiss equestrians (110 female and 10 male) were assessed for their PF for this study. This ratio of males to females is reflective of the male to female ratio in the Swiss riding population (Bianchi, 2014).

Table 1 illustrates the study inclusion and exclusion criteria. Voluntary participants fulfilling the criteria were randomly selected by an assistant and stratified according to the sex of the horses, the distribution of the region and riding discipline, according to the Switzerland-wide prevalence of horses in 2014 (Bianchi, 2014). One veterinarian and one physiotherapist (PT), specialised in musculoskeletal disorders, assessed the exclusion criteria immediately before data collection. The required sample size was $n \geq 106$ (Equation 1) (Green, 1991):

$$n = 50 + 8 \times m \quad (1)$$

where n = number of subjects and m = number of predictors (m=7 for this study)

Procedure

Test conditions were standardised. One PT conducted all PF measurements, while two national and independent equestrian judges (EJs) scored the equestrians RP based on video recordings. All of these persons participated in training sessions prior to the first measurements. The PT practiced the physical fitness tests during three four-hour

Table 1. Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
main equestrian of the participating horse (minimum 2/3 of the time, minimum one hour per week)	discipline of race-riding
age of equestrian ≥18	acute illness, injury or other issues which restricts the (self-determined) usual riding ability of the participant horse or equestrian
age of horse ≥5 and ≤18	

long training sessions. The EJs practiced their scoring, twice, with ten example videos and reached consensus on their ratings if those diverged more than two points on any item in between the two ratings.

The PT carried out the 1 h PF tests, assessing seven components of PF (balance, endurance, flexibility, reaction, speed, strength and symmetry; Table 2) (Hegner *et al.*, 2000). The flexibility of the hip (flexion, extension, internal/external rotation and abduction), knee (flexion) and foot (dorsiflexion) were measured bilaterally using a digital goniometer (Halo Medical Devices, Perth, Australia). Balance was quantified through performing static and dynamic balancing exercises on a three-dimensionally unstable chair (Balimo®Wood; Advivinova GmbH, Quickborn, Germany). Strength of the lower extremities (hip flexors, hip extensors, hip abductors, hip adductors and knee flexors), the back and the abdomen were assessed using a handheld dynamometer (microFET2®; Hoggan Scientific, Salt Lake City, UT, USA). An accelerometer system (Humotion®; Humotion GmbH, Münster, Germany) was used for evaluating explosive strength and reaction of the lower extremities. For the upper extremities, the reaction was measured with a conventional reaction test (Del Rossi *et al.*, 2014). A 3 min step test was performed to assess endurance capacity (Bohannon *et al.*, 2015). The symmetry of each participant regarding the components of balance, flexibility, reaction and strength was calculated and summarised under the domain 'symmetry'.

Table 2. Test description of physical fitness.

No.	Item	Outcome, units of measurement
Flexibility		
1-2	Knee: flexion	Joint angle right & left [°]
3-4	Hip: flexion	Joint angle right & left [°]
5-6	Hip: abduction	Joint angle right & left [°]
7-10	Hip: rotation (internal, external)	Joint angle right & left [°]
11-12	Hip: extension	Joint angle right & left [°]
13-14	Ankle: dorsiflexion	Joint angle right & left [°]
Balance		
15-26	Static, unilateral	[number of completed tasks]
27-32	Dynamic, unilateral	[number of completed tasks]
33-36	Static, bilateral	[number of completed tasks]
37-38	Dynamic, bilateral	[number of completed tasks]
Speed		
39-40	Tapping	Maximum & mean frequency [Hz]
41-43	Jumps	Height [cm]
Reaction		
44-45	Reaction: hand	Right & left [cm]
46	Reaction: legs	Reactive force [ms]
Strength		
47-48	Hip: extension	Maximal strength right & left [kg]
49-50	Hip: flexion	Maximal strength right & left [kg]
51-52	Hip: abduction	Maximal strength right & left [kg]
53-54	Hip: adduction	Maximal strength right & left [kg]
55-56	Knee: flexion	Maximal strength right & left [kg]
57	Back	Maximal strength [kg]
58	Abdominal	Maximal strength [kg]
Endurance		
59	3 min step test	Difference: maximum bpm and after 1 min of recovery [bpm]

The 10 min riding test included the halt and all paces of the horse (walk, rising and sitting trot, canter) in both riding directions (Table 3). The test was read aloud by an experienced veterinarian. The riding test was documented and recorded using a digital camcorder (Sony Europe Limited, Weybridge, UK) mounted on an automatic tracking robot which followed the radio emitter fixed to the horse's noseband (Pixio®, Move'n See, Brest, France).

Each participant's experience in horse riding (in years), hours of riding per week, RP self-assessment, motivation for the PF test (test-motivation) and other demographics were collected via an online-survey. This survey comprised more than 100 questions about the equestrian and the horse and was part of the 'Back health of the Swiss riding horse population – a survey study' (ARAMIS-No. 2.16.10) study.

Variables and data processing

We used standard predictor variables, or in other terms the mean z-values of the seven components of PF. Standardisation to z-values was performed to compare the effects of variables of different magnitude; for example knee flexion and hip abduction range of motion (ROM) might have a very different magnitude making it difficult to compare absolute values (Table 2).

The two EJs rated each video retrospectively and independently from each another. The rating included twenty criteria (e.g. equestrian's seat), each of which was rated on a numeric rating scale from one (not executed) to ten (excellent). The maximum RP was 400 points (200 points per EJ).

Statistics

A linear model for RP, including the components of PF and the potential confounders of body mass index (BMI), experience, hours of riding per week and test-motivation, was fitted to the data. Thus, the full model for each observation of RP, illustrated in Equation 2 was:

Table 3. Test description of riding performance.

No.	Item	Criteria	Units of measurement[1]
1	Halt	Seat, influence of the rider, obedience, precision of the figures	[0-10]; interval
2	Walk, right	Seat, influence of the rider, obedience, precision of the figures	[0-10]; interval
3	Rising trot, right	Seat, influence of the rider, obedience, precision of the figures	[0-10]; interval
4	Sitting trot, right	Seat, influence of the rider, obedience, precision of the figures	[0-10]; interval
5	Canter, right	Seat, influence of the rider, obedience, precision of the figures	[0-10]; interval
6	Walk, left	Seat, influence of the rider, obedience, precision of the figures	[0-10]; interval
7	Rising trot, left	Seat, influence of the rider, obedience, precision of the figures	[0-10]; interval
8	Sitting trot, left	Seat, influence of the rider, obedience, precision of the figures	[0-10]; interval
9	Canter, left	Seat, influence of the rider, obedience, precision of the figures	[0-10]; interval
10	Rider	Position, balance, suppleness	[0-10]; interval
11	Rider	Aids: correctness of application, timing, influence, sensitivity	[0-10]; interval
12	Horse	Gait: clearness, tactfulness, rhythm	[0-10]; interval
13	Horse	Engagement, impulsion, activity	[0-10]; interval
14	Horse	Connection: released, activity of the mouth, collection, elevation	[0-10]; interval
15	Horse	Alignment, bending of body	[0-10]; interval
16	Horse	Back activity, elasticity	[0-10]; interval
17	Horse	Obedience: concentration, attention, motivation	[0-10]; interval
18	Overall impression	Synchronousness: equal movement of horse and rider	[0-10]; interval
19	Overall impression	Appearance, proportion of dimensions	[0-10]; interval
20	Overall impression	Harmony: satisfaction horse, confidence	[0-10]; interval

[1] Unit scale: 10 = excellent, 9 = very good, 8 = good, 7 = quite good, 6 = satisfactory, 5 = sufficient, 4 = insufficient, 3 = quite bad, 2 = bad, 1 = very bad, 0 = not executed.

$$\begin{aligned}\mathrm{RP}_i = \beta_0 &+ \beta_1\mathrm{balance}_i + \beta_2\mathrm{endurance}_i + \beta_3\mathrm{flexibility}_i\\ &+ \beta_4\mathrm{reactiontime}_i + \beta_5\mathrm{speed}_i\\ &+ \beta_6\mathrm{strength}_i + \beta_7\mathrm{symmetry}_i + \beta_8\mathrm{BMI}_i\\ &+ \beta_9\mathrm{experience}_i + \beta_{10}\mathrm{ridinghours}_i\\ &+ \beta_{11}\mathrm{testmotivation}_i + \varepsilon_i \qquad (2)\end{aligned}$$

With β_0 representing the intercept, β_k the weight of the covariates and ε_i the independent and normal distributed errors $\varepsilon_i N(0,\sigma^2)$. No interaction effects were integrated into the model.

To achieve a good compromise between model fit, complexity and interpretability, the model was reduced. A stepwise backward regression was performed using partial F-tests (with criterion P>0.1). The coefficient of determination (R^2) was computed to specify the amount of variance that is explained by the model. In field research, an explanation of 20-30% of the variance can be interpreted as good (Persike, 2012). Significance level was set at alpha=0.05. Residual analysis was performed to check model assumptions.

Intraclass correlation coefficient (ICCA1) estimates and their 95% confidence intervals (CI) were calculated based on a single rating, absolute agreement, two-way mixed effects model (McGraw and Wong, 1996). Additionally, the Pearson correlation of RP and RP self-assessment was investigated. All data were analysed with SPSS 24 (IBM, Armonk, NY, USA). The STROBE Statement checklist was used for strengthening the reporting of observational studies (Von Elm *et al.*, 2007).

3. Results

Participants

Three participants were excluded: two dues to lameness of their horses and one due to acute injury of the equestrian. Two participants cancelled the testing at short notice. 115 participants (106 female, 9 male) remained for analysis. Table 4 shows the characteristics of the participants. Descriptive statistics of PF can be found in Table 5.

Multiple regression

The optimal model, which was a compromise between model fit and model complexity, was found to be:

$$\begin{aligned}\widehat{\mathrm{RP}}_i = 224.2 &+ 14\times\mathrm{endurance}_i - 7.9\times\mathrm{flexibility}_i\\ &+ 6.4\times\mathrm{reactiontime}_i + 8.5\times\mathrm{strength}_i \qquad (3)\end{aligned}$$

Table 4. Descriptive statistics of the equestrians.

Riding performance (RP)	Mean ± SD[1]
RP (0-400 points)	224.2±42.9
RP riding judge 1 (0-200 points)	113.3±20.6
RP riding judge 2 (0-200 points)	110.9±23.2
RP self-assessment (NRS 0-10, 10 is highest)	6.5±1.1
Physical fitness (PF)	**Mean ± SD**
Motivation to participate in the test (NRS 0-10, 10 is highest)	8.8±1.6
Equestrians' characteristics	**Mean ± SD (range)**
Age (years)	35.7±10.6 (18 to 64)
Body mass index (kg/m^2)	23.2±3.5 (17.2 to 33.3)
Experience horse riding (years)	24.5±9.7 (7 to 62)
Hours of horse riding (h/week)	8.2±3.5 (1 to 25)
Further characteristics	**Absolute frequencies (n) (relative frequencies (%))**
Sex	
female	106 (92.2)
male	9 (7.8)
Riding level	
brevet	83 (72.2)
license	56 (48.7)
Riding discipline	
show jumping	39 (33.9)
leisure riding	34 (29.6)
dressage	30 (26.1)
eventing	6 (5.2)
endurance	3 (2.6)
western	3 (2.6)

[1] SD = standard deviation.

Equation 3 illustrates that endurance, flexibility, reaction and strength were associated with RP. 16.7% of the variance in RP was explained by the four aforementioned components of PF. The coefficient of flexibility was negative, meaning that the direction of association was reversed (Table 6). This signifies that RP increased when flexibility decreased.

The regression model and its coefficients were significant $P<0.05$, except for reaction (Table 6).

Residual analysis showed that the model assumptions were met. According to the recruitment process, a random sample selection was carried out. The mean and the homoscedasticity of the residuals were considered good. The residuals were approximately normally distributed. There was no evidence for multicollinearity.

Reliability of the EJs and correlation between RP and RP self-assessment

ICC values ≥0.9 indicate excellent reliability and ICC values between 0.75 and 0.9 indicate good reliability (Koo and Li, 2016). The level of inter-rater reliability of the two EJs can be interpreted as 'good' to 'excellent' (ICC=0.9, 95%CI: 0.86-0.93) (Koo and Li, 2016). Pearson correlation of r=0.1 indicates small, r=0.3 medium and r=0.5 large linear relation (Cohen, 1988). Pearson correlation of RP assessed during the riding test and self-assessment of RP was medium (r=0.3, P=0.00) (Cohen, 1988).

4. Discussion

The findings show that the PF components of endurance, flexibility, reaction and strength are associated with RP. Endurance, reaction and strength are positively associated with RP, whereas the association between flexibility and RP is negative. The coefficients correspond to RP changes per unit (SD) increase on the corresponding covariate, adjusted for the other covariates in the model. As an example, RP increases by 14 points (95%CI: 6.6-21.3) if endurance increases by one SD and all other covariates remain constant.

No association with RP was found for equestrians' balance, speed, symmetry, BMI, experience in horse riding, hours of riding per week or test motivation. The linear relationship of RP and RP self-assessment was medium (r=0.3, P=0.00). The inter-rater reliability of the EJs is considered as 'good' to 'excellent'. The high number of participants could have increased the significance of the result.

Interpretation and comparison with the literature

Theoretically, it is reasonable to conclude that better endurance, reaction and strength are associated with higher RP. As with other sports, high levels of aerobic endurance capacity and reaction time are beneficial in horse riding (Koch *et al.*, 2012). In order to consistently adjust in response to the movement of the horse, the equestrian requires strong muscles (Heipertz, 1991). Abdominal and back strength endurance is responsible for an upright sitting position (Koch *et al.*, 2012). Strength endurance of the thighs is needed for the aids and the rising trot (Koch *et al.*, 2012). It cannot be evaluated from this study whether the activity of abdominal stabilising muscles is higher in experienced equestrians (Terada, 2000).

The negative association of flexibility and RP could be explained by a physiological adaption due to riding. Another

Table 5. Descriptive statistics of physical fitness.[1]

No.	Item of physical fitness	Unilateral[1] (mean ± SD[2])		Bilateral (mean ± SD)
		Dominant	Non-dominant	
	Flexibility			
1-2	Knee: flexion (°)	154.4±7.2	153.7±6.8	
3-4	Hip: flexion (°)	148.7±6.9	149.6±5.1	
5-6	Hip: abduction (°)	39.3±6.1	36.4±5.7	
7-8	Hip rotation, external (°)	49.4±11.5	51.2±9.8	
9-10	Hip rotation, internal (°)	40.7±11.6	41±10.4	
11-12	Hip: extension (°)	6.9±4.7	6.5±4.8	
13-14	Ankle: dorsiflexion (°)	36.5±5.7	39.4±5.9	
	Balance			
15-26	Static, unilateral (number of completed tasks)	5.3±1	5.4±1	
27-32	Dynamic, unilateral (number of completed tasks)	1.5±0.8	1.5±0.7	
33-36	Static, bilateral (number of completed tasks)			2.4±0.9
37-38	Dynamic, bilateral (number of completed tasks)			0.1±0.4
	Speed			
39	Tapping, mean (Hz)			8.5±1.4
40	Tapping, maximum (Hz)			12.4±2.5
41	Squat jump (cm)			29.4±4.4
42	Countermovement jump (cm)			30.3±4.4
43	Drop jump (cm)			29.5±4.8
	Reaction			
44-45	Reaction: hand (cm)	0.2±0.1	0.2±0.1	
46	Reaction: legs (ms)			213.8±45.0
	Strength			
47-48	Hip: extension (kg)	69.5±15.3	69.2±16.7	
49-50	Hip: flexion (kg)	30.3±4.5	29.8±4.3	
51-52	Hip: abduction (kg)	21.6±3.6	20.9±3.7	
53-54	Hip: adduction (kg)	19.4±3.5	19.4±3.2	
55-56	Knee: flexion (kg)	26.9±3.9	26.8±3.8	
57	Back (kg)			46.6±8.7
58	Abdominal (kg)			26.3±3.3
	Endurance			
59	3 min step test (bpm)			12.6±9.9

[1] Used for symmetry calculation.
[2] SD = standard deviation.

Table 6. Final model fit.

	Regression coefficient	95%CI[1]	SE[2]	t-value	*P*-value
Intercept	224.2	217 to 231.4	3.7	61.4	0.00
Endurance	15	6.6 to 21.3	3.7	3.8	0.00
Flexibility	-7.9	-15.4 to -0.5	3.8	-2.1	0.04
Reaction	6.4	-1 to 13.7	3.7	1.8	0.09
Strength	8.5	1.2 to15.8	3.7	2.3	0.02

[1] CI = confidence interval.
[2] SE = standard error.

explanation could be that flexibility of the equestrian is lowered in favour of stability. Both assumptions do not quite agree with other research, which regard flexibility as a precondition for a supple seat (Heipertz-Hengst, 2002; Meyners and Putz, 1992). In this light, it is conceivable that there is a curvilinear shaped relationship between flexibility and RP. Both reduced and increased flexibility might be associated with different aspects of RP indicating, for instance, that higher flexibility is beneficial to a supple seat, while overall, reduced flexibility is beneficial to an overall better RP.

Various authors have recognised equestrian's asymmetry and its relation to saddle pressure distribution, seated postural stability, and potentially musculoskeletal pain, this study did not confirm the assumption that asymmetry is a negative predictor for RP (Gunst *et al.*, 2019; Hobbs *et al.*, 2014; Nevison and Timmis, 2013).

Contrary to the theory, this work shows that an equestrian's balance, speed, symmetry, hours of riding per week and experience of horse riding have no association with RP (Greve and Dyson, 2013; Koch *et al.*, 2012; Lagarde *et al.*, 2005). Two main reasons could be responsible for this result: (1) a theoretical overestimation of these factors; (2) an erroneous test selection. As an example, the speed measurement consisted of jumps, which is an atypical exercise for horse equestrians. For the same reason, the open kinetic chain balance test could be criticised. The years of experience of horse riding do not tell how long a pair does train together. The findings that horse-riding experience and/or hours of riding per week were not associated with RP was somewhat surprising. Possibly experience and hours of riding per week are inextricably linked with the analysed components of PF. Furthermore, experience is not equal to the time the horse and equestrian have been training together, or to the training level of the horse or equestrian. Especially because our population consists of many leisure riders.

The 'good' or 'excellent' ICC should enhance the reputation of the EJs. At the same time, this result shows that slight deviations in the judgement of horse riding is to be expected. The medium linear relationship between RP and RP self-assessment shows that subjective and objective assessments do not fully agree. Thus, an objective assessment is required to investigate RP.

The achieved 16.7% of variance explanation is below the 20-30% that can be regarded as good in field research (Persike, 2012). The reason for this rather low percentage could be that the requirement profile of an equestrian is comprised of more skills than those examined in this study. Cognitive skills, such as anticipation and decision-making, seem to be essential (Koch *et al.*, 2012; McBride and Mills, 2012; Weineck, 2007). In addition, coordinative skills, rhythm and selectivity are demanded (Koch *et al.*, 2012; Weineck, 2007). Further factors, other than the equestrian himself, could also have an influence on RP, e.g. the saddle and the health of the horse.

Limitations

The recruitment procedure required initiative on behalf of the equestrian and a selection bias could have been introduced. Potential confounders of RP could have been the nervousness of horse and equestrian due to the unusual conditions. A video-recording of only two-dimensions, as well as a riding test with a predominance of dressage criteria, could also have biased the judgement of RP. The self-reporting of the equestrians' qualifications may have led to an information bias. Due to the low number of male equestrians and the variety of disciplines, no subgroupings could be made. Other relevant factors, such as the horse itself or the saddle, were not considered. The results of this study can therefore only be generalised for hobby equestrians, but not for all equestrians. Juniors and top athletes, especially, were not given sufficient consideration in this work. The EJs were more experienced in the dressage discipline; this may have skewed the results.

Compared to our initial hypothesis, the association of endurance with RP seems to be very high in contrast to the other covariates. No conflict with the prior hypothesis was found for the other results. The models and subsequent interpretations assumed a linear relationship between RP and the components of PF. Other relationships are possible, but these were not addressed in this study.

5. Conclusions

Findings suggest that PF is associated with RP. The PF components of endurance, reaction and strength are positively associated with RP, whereas flexibility is negatively associated. No association was found for other factors, such as equestrian's balance, speed, symmetry, BMI, experience, hours of riding per week, or test-motivation.

Further research

PF in non-equestrian, bilateral sports, such as alpine skiing, should be examined to assist in the improvement of sport-specific training and therapy. In particular, the relationship of back to abdominal muscles, knee flexors to knee extensors, or hip abductors to hip adductors, would be worth measuring to clarify the importance of symmetry in equestrian and other bilateral sports. In addition, cognitive, such as power of concentration, and coordinative skills, such as differentiation ability or orientation skills, need to be investigated to determine their influence on RP. Furthermore, correlations of RP with the saddle fit or the health of the horse could be considered. In future work it may be beneficial to focus on one discipline and calibre of rider. Comparing show jumping, leisure riding, and dressage riders may have confounded the results.

Physiotherapeutic relevance

As well as sports physiotherapists, the results of this study could be of interest to the International Federation of Equestrian Sports and athletics' coaches. The findings on the importance of an equestrian's PF is of great value. It implies that current training concepts should be adapted to have a greater focus on PF. Specific attention should be given to the components of endurance, flexibility, reaction and strength. Future research should also investigate whether similar conclusions can be drawn for the PF of young people and top athletes.

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Competing interests

The authors declare that there are no conflicts of interest.

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