A PILOT STUDY ON ITALIAN EVENTING PROSPECTIVE OLYMPIC HORSE RIDERS PHYSIOLOGICAL, ANTHROPOMETRICAL, FUNCTIONAL AND ASYMMETRY ASSESSMENT

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Abstract The purpose of the study was to measure anthropometry, isometric force, balance, functional movement quality and asymmetries and peak oxygen uptake of prospective Rio 2016 Olympic Games Eventing horse riders (five males and two females: age 26–41 years, height 173.0 ±8.9 cm, weight 66.4 ±11.1 kg, BMI 22.0 ±1.8 kg·m^{-2}, FEI ranking 33–409). Mean and maximal isometric of the hands were approximately 45 kg, and 50 kg, respectively. Total maximal isometric force of the lower limb resulted 372.6 kg for the extensor muscles, and approximately 58 kg for the adductor muscles. Mean composite functional movement score was 14.1, mean Bunkie score 3.4, Y-balance score 93.1 ± for the left side and 90.9 for the right one. V̇O$_2$peak values ranged between 2.4 and 4.2 l·min^{-1} and 46.8 and 59.7 ml·kg^{-1}·min^{-1}. The oldest and more experienced athletes had a greater postural control on the anterior direction. The athletes with a superior FEI ranking had a greater postural control. Subjects had high maximal isometric strength of the hands and lower limbs, good physical functions parameters, balance and maximal aerobic power and few muscular strength and balance asymmetries.

Key words: elite athletes, physical evaluation, asymmetry, performance

Introduction

Many athletes show signs of skilled sporting potential and talent identification programs are intended to recognize those athletes who possess remarkable potential for success. Many attempts have been made to develop methods to identify remarkably gifted athletes at an early age so as to focus available resources on particularly promising individuals and to promote their development in a certain sport. This process can be considered most beneficial for sport disciplines with a small number of participants at highly competitive levels, that can only rely on a small pool of gifted individuals. Moreover, a systematic review on talent identification in sport revealed that only three sports (soccer, gymnastics, and rugby league) were represented more than once in literature. This lack of diversity makes it very difficult to draw inferences about the predictive utility of testing variables. Authors concluded that there remains a substantial amount of information that we have yet to learn in this field and that future work should include a greater diversity in study designs (e.g. variables, samples, etc.) to reflect the considerable diversity in high performance sport (Johnston, Wattie, Schorer, Baker, 2018).

This is even more true when it comes to horse riding disciplines for whom scarce is the information on physical and anthropometrical profiles of elite level riders. Indeed, neither the physical, physiological, nor biomechanical traits required by riders, nor the most beneficial type of training for this population of athletes have been extensively investigated.

Eventing originally evolved from the training of cavalry horses. The sport is rather like the pentathlon in that it combines different disciplines in one competition and is run on a cumulative penalty basis. Eventing is a three-phase competition. Phase 1 is the dressage (DR) test that comprises a set sequence of compulsory movements at a relatively low speed in an area that is 20 m wide and 40 m long (60 m at higher levels of competition). Phase 2 is the cross-country (XC) test, in which the horse and rider negotiate a series of solid natural obstacles while galloping across the country. Phase 3 is the show jumping (SJ) test, where the horse and rider combination is required to complete one round of jumping over approximately 12 coloured fences within a set time. There are 5 classes, increasing in length, speed and technical difficulty, in which horses may compete according to their level of skill and fitness from introductory level 1* to Olympic level 5*. The modern 3-day-event is conducted over 3 or more days and is run in accordance with rules set by the Fédération Equestre Internationale (FEI). The Cross-Country day is the most physically demanding of the 3 disciplines. It is the cornerstone of Eventing, and proves the speed, endurance and jumping ability of the horse over varied terrain and solid obstacles. This phase is ridden at a gallop over 7,400 m and features solid fences (up to 45) as well as natural obstacles such as water, ditches, drops and banks. The sport of Eventing is a great all-round test of horse and rider and a tremendous examination of horsemanship and is renowned for being one of the most challenging equestrian sports for both horse and rider (Roberts, Shearman, Marlin, 2009).

Even though physical fitness is required by the equestrian athlete for maintenance of balance and effectiveness, scientific research concerning the physiological demands of horse riding is very limited. In the interest of the horse, however, fitness and competence of the rider are regarded as essential. There is, indeed, uniqueness about equestrian sport as the horse has its own free mind. This combined horse-human partnership adds further complexity and variability to the control of extraneous variables and events in scientific investigations (Roberts et al., 2009). Bompa and Haff (2009) suggested that the dominant motor abilities horse riders should possess are strength, reaction time, balance, and endurance. However, the available studies were mostly conducted on female riders who were not at a competitive level. Therefore, research using male and competitive equestrians were suggested to be

beneficial to present a clearer picture of a competitive equestrian population (Douglas, Price, Peters, 2012). More recently, Sung and colleagues (Sung et al., 2015) investigated comprehensive ranges of parameters such as change of lactate, heart rate, calorie, V̇O_2max, skeletal muscle mass, body water, body fat, etc between male amateur and professional horse riders, emphasizing that more successful athletes possess a combination of physical attributes, talent, skill, technique, determination, strategy, and psychological preparedness.

Undeniably, sport practice constraints athletes to manage simultaneous sources of information to maintain postural stability in an efficient manner. Impaired balance is one of the several risk factors that have been associated with increased risk of lower extremity injuries. Research suggested deficits in static and dynamic balance discern between individuals with a history of ankle sprains, chronic ankle instability, anterior cruciate ligament deficiency, and anterior knee pain (Shaffer et al., 2013). The contribution of sensory information to postural control has been shown to differ according to the sport activity and the level of practice. In a recent review, Paillard (2017) concluded that repeated particular postures and movements, induced by sport practice, could generate robust postural adaptations. This would be especially the case when the sport practice induces a high level of postural balance as in horseback riding where, maintaining postural stability, is a critical constraint to ensure safety and avoid falls. At this regard, horseback riders exhibited greater stability during a dynamic balance test, compared to non-athletes. Authors suggested that horseback riding could help developing particular proprioceptive abilities on standing posture as well as better postural muscle tone during particular bipodal dynamic perturbations (Olivier, Viseu, Vignais, Vuillerme, 2019). On the other hand, anatomical, functional, and dynamical asymmetry in a large sample of riders has been reported. At this regard, authors suggested that the demands on horse riders competing at higher levels may predispose these riders to a higher risk of developing asymmetry and potentially chronic back pain rather than improving their symmetry (Hobbs et al., 2014). Indeed, riders frequently complain about orthopaedic problems, possibly related to musculoskeletal stress reactions. Low back, hip joint, and hamstring muscle pain are the most common symptoms among competitive riders. A cross-sectional survey among competitive athletes, members of the Italian Equestrian Sport Federation showed that low back pain had a prevalence of 91.6% and 74.2% for lifetime and 1-year, respectively (Ferrante, Bonetti, Quattrini, Mezzetti, Demarie, 2021). An evaluation of the orthopaedic problems encountered by elite horseback riders revealed that 88% of riders suffer of back pain. The predominant reason for back pain in the rider has been suggested to be functional, as attributed to muscular disbalance (Kraft et al., 2009). Asymmetric forces are suspected of having negative effects on rider-horse interaction through weight aids, athletic performance, and health of the horse. Analysis on saddle pressure pattern revealed that the asymmetric loading is influenced by various factors of functional and anatomical asymmetry of rider and horse; a possible explanation for the rider's lateral shift could be anatomical asymmetries of the horse related to its laterality (Gunst et al., 2019). Although the risk of musculoskeletal conditions and injuries is multifactorial, preliminary evidence suggests that neuromuscular and strength training programs may be beneficial for preventing the occurrence of these conditions (Teyhen et al., 2012).

A deeper knowledge of elite level horse riders' characteristics may be useful for coaches and athletes to gain better performance and to address health promotion issues. Therefore, the purpose of this study was to identify the anthropometric, ergonomic, functional, and physiological profiles of the prospective Eventing horse Italian riders for Rio 2016 Olympic Games and to evaluate any relationship between the measured parameters and their international ranking and years of competitions. Symmetry in ergonomic and functional outlines was also assessed.

Methods

Participants

Subjects were seven (five males and two females) Eventing horse riders being part of the prospective team for the Rio 2016 Olympics. Since Horse riding is the only Olympic discipline in which male and female competitions are not separate as gender, data were processed together as one group. Subjects were included in the study if they have participated in Eventing competition at international level regularly for at least 10 years and kept a consistent training schedule in the last year. Performance level was assessed through the Fédération Equestre Internationale on-line ranking (FEI rank). All subjects trained 4–6 hours a day on different horses and practiced 2–4 hours a week of other sport activities at leisure level such as jogging. Exclusion criteria included: if they had reported a recent (within the past 6 weeks) musculoskeletal or head injury that was likely to affect their motor performance. The research was conducted in accordance with the 1964 Helsinki Declaration.

Design and Procedures

The study was approved by the Italian Olympic Committee. All subjects were required to review and sign a consent form prior to participation.

Measures were undertaken at the end of June 2016, approximately 6 weeks prior the Rio Olympic Games. Each test was performed on separate days, with at least 24h rest in between. The subjects were instructed to avoid same-day exercise prior to testing and be in a euhydrated state with empty bladder and bowel at the time of the test.

Measures

Maximal Isometric Strength (MIS) has been assessed by three different tests: Handgrip test (Ht), Lower limb extensor muscles (Emf), Lower limb adductor muscles (Amf). Maximal isometric strength of the forearm muscles (Ht) was measured from both hands. The subject was sitting comfortably on a chair with the shoulder adducted and neutrally rotated, with the elbow against the body and flexed at 90°, and the forearm and wrist in a neutral position. The subject held the dynamometer (Jamar Hydraulic Hand Dynamometer, J.A. Preston Corporation, Clifton, NJ) in the hand to be tested. The handle of the dynamometer was adjusted if required. Three maximal attempts lasting 20 s were recorded one hand at a time. The subjects were provided with a rest period of 2 min to control for the effects of fatigue. The maximum reading for each hand was used for further analysis. Force was expressed as maximal value (Fmax), mean value (Fmean) and decrease in maximal force along the duration of the test (Decrease), representing the muscle endurance for each hand. Lower limbs maximal isometric strength was evaluated with an isometric squat. It was performed by having the subject stand on two force platforms (Desmotech D11 Version Sport Pro, Italy) at a 100° knee angle. The subject was linked at the waist to the assessment station to ensure no displacement during isometric contractions. His/her elbows were bent at 90°, hands on waist, eyes looking forward. On verbal command the subject performed a maximum knee isometric contraction of the extensor muscles for 3–5 s. A minimum of three maximal actions were recorded and the best maximum was taken for further analysis. Three-min rest was allowed between trials. The peak force of the lower limbs adductors was measured using a commercial strain gauge (Iso control, Globus, Italy) mounted on an adductor machine. The load cell was secured in series with the sliding axis of the adductor machine seat using two chains attached to the adductor machine frame, so that the direct line of force was registered. Before each trial, the load cell was reset to zero to

negate the force produced on it by the two tensed chains. The participants were required to exert force as hard and as fast as possible for 3–5 s. Three trails were performed interspersed with 3-minute of rest. Peak force (the highest force recorded) was calculated.

Three functional performance tests were performed: Functional Movement Screen (FMS), Bunkie test (Bt), Y-Balance test (YBT). The FMS consists of 7 fundamental movement component tests that are scored on a scale of 0 to 3, with the sum creating a composite score ranging from 0 to 21 points (Kraus, Schütz, Taylor, Doyscher, 2014). Athletes, after obtaining verbal instructions and a brief demonstration of each sub-test, were not 'coached' through the movement, and were blinded to the scoring criteria of each sub-test. Testers were blinded to the scores of subsequent stations. We established a-priori that a composite FMS score of ≤14 would be used as a cut-off, as previously reported (Bonazza, Smuin, Onks, Silvis, Dhawan, 2017). The Bt consists of 40 s isometric exercise in 5 testing positions with each test performed bilaterally (Ronai, 2015). The time that one was able to maintain the proper test position without pain was recorded in seconds using a stopwatch. A test was terminated when a subject was no longer able to maintain the proper test position. Between testing positions a rest interval of 2 min was granted (O'Neill, Tamjid, DeRevere, Kostelis, 2019). Order of testing was randomized per each subject. Test termination occurred when either (a) the subject stopped the test due to fatigue or (b) the subject was unable to maintain the correct position (Brumitt, 2015). A 4 score was given when the movement was terminated between 31 and 40 s, a 3 score was given when the movement was terminated between 21 and 30 s, a score of 2 was given when the movement was terminated between 11 and 20 s, a score of 1 was given when the movement was terminated between 1 and 10 s and a score of 0 was given when the subject could not maintain the position at all. According to YBT procedure, participants completed 3 consecutive trials for each reach direction and, to reduce fatigue, subjects altered limbs between each direction. Attempts were discarded and repeated if the subject failed to maintain unilateral stance on the platform, failed to maintain reach foot contact with the reach indicator on the target area while the reach indicator is in motion, used the reach indicator for stance support, or failed to return the reach foot to the starting position under control. Average reach distance in cm over 3 trials were calculated for both limbs in the anterior, posteromedial, and posterolateral directions, the composite score (CS) was computed by adding all 3 reach directions together and then normalizing to leg length. The asymmetry score assesses the difference between the right and left reaching (Shaffer et al., 2013).

Peak Oxygen Uptake (V̇O$_2$peak) was determined through an incremental running test on a motorized treadmill (Run Race, Technogym, Italy), with continuous gas measurements breath by breath at the mouth by a miniaturized telemetric metabolimeter (K5, Cosmed, Italy) with a 15 s sampling rate. Heart rate was also continuously monitored (HRM-Dual™ Ant+, Garmin, USA). A warm-up of 10 minutes of running preceded the incremental test. Thereafter treadmill velocity was set at 9 km·h^{-1} and increased by 0.5 km·h^{-1} each minute until volitional exhaustion, i.e. when the subjects were unable to run at the required velocity. V̇O$_2$peak was calculated as the highest value attained at the end of the test with data averaged at 15 s interval and the maximal heart rate achieved during the test was defined as HRmax. V̇O$_2$peak was accepted if a proximity of ≤5 beats·min^{-1} to theoretical HRmax (208 – 0.7 × age) was attained.

Statistical Analysis

The analyses were performed using the software StatView version 5.0.1. Data were expressed as median ± IQR. Nonparametric tests were used because of the small sample size. Differences between limbs (left vs right)

were performed with Mann-Whitney U test. Cohen's effects size (ES) was also computed (Fritz, Morris, Richler, 2012). Spearman Rank Correlation analyses were used to understand possible relationships between physiological parameters and age, FEI ranking, and competition years. Statistical significance was set at $p < 0.05$.

Results

Anthropometric values, FEI ranking and years of competition are presented in Table 1. Age ranged from 26 to 41 years, height from 158 to 187 cm, weight from 47 to 80 kg and BMI from 18.8 to 24.2 kg·m^{-2}. All athletes were young adults and normal weight. FEI ranking ranged from 33 to 409, while years of competition ranged from 12 to 20.

Table 1. Anthropometry, ranking and competition years

	Median ± IQR	Range (min–max)
Age (yrs)	31.4 ±4.8	26–41
Height (cm)	173.0 ±8.9	158–187
Weight (kg)	66.4 ±11.1	47–80
BMI (kg·m^{-2})	22.0 ±1.8	18.8–24.2
FEI ranking	210.7 ±160.3	33–409
Competition (yrs)	16.3 ±2.9	12–20

Values are expressed as median ± IQR.

Maximal isometric strength results are illustrated in Table 2. Left hands had greater maximal (+2.6 kg) and mean (+0.5 kg) forces than the right ones for all subjects, and force decrease was significantly higher for the right hands, with a large effect (+5.1 kg; $p = 0.048$; ES = 0.7). All subjects presented higher performance of the left hands even though differences were not statistically significant.

Total maximal force of the lower limb extensor muscles resulted 372.6 kg. Left extensor muscles expressed a maximal force 23.2 kg higher than the right ones, non-statistically significant. A 1.6 kg higher maximal force of the left adductor muscles was observed, non-statistically significant.

Table 2. Maximal Isometric Strength (MIS)

	Max L	Max R	Mean L	Mean R	Decrease L	Decrease R
Handgrip Test (kg)	51.9 ±26.8	49.3 ±22.7	45.5 ±19.8	45 ±20.1	14.4 ±9.3	19.5 ±5.7
	Max L		Max R		Range (min–max)	
Lower limb extensor muscles (kg)	197.9 ±102.0		174.7 ±95.7		94–227.9	
Lower limb adductor muscles (kg)	58.8 ±19.1		57.2 ±18.4		33.2–69	

Values are expressed as median ± IQR.

Functional performance tests results are displayed in Table 3. Mean Composite Functional Movement Score was 14.1 (median ± IQR: 14 ±1.75; range: min 13 – max 17). Left and right side had almost identical scores for all items, except for one subject who achieved higher values on the left side for hurdle step (HS) and active straight leg raise (LR). No statistical differences between L and R were detected.

Mean Bunkie score was 3.4. Left and right side had almost identical scores for all items, except for one subject who achieved higher values on the left side for anterior power line (APL) and another one on the right side for posterior power line (PPL). Difference between left and right Bunkie test results was not statistically significant.

According to the Composite Balance Score, left side had 2.2 cm higher values than the right one. Lowest values were displayed for the Anterior balance, highest values for the Posteromedial balance and intermediate values were exhibited in the Posterolateral balance. Anterior values were significantly higher for the left side, with a large effect ($p = 0.035$; ES = 0.8), participants exhibiting an anterior reach asymmetry of 3 cm.

Table 3. Functional performance tests

	Left	Right	Range (min–max)
Functional Movement Screen (FMS)			
Deep squat	2 ±0		1–2
Stability push-up	2 ±1		1–3
In-line lunge	2 ±0	2 ±0	2–3
Hurdle step	2 ±1	2 ±0.75	2–3
Shoulder mobility	3 ±0	3 ±0	2–3
Active leg raise	1 ±1.75	1 ±1	1–3
Rotary stability	2 ±0	2 ±0	2–2
Bunkie test (Bt)			
Posterior power line	4 ±1	3 ±1	3–4
Anterior power line	4 ±0	4 ±0	3–4
Posterior stabilizing line	3 ±0.75	3 ±0.75	3–4
Lateral stabilizing line	3 ±0	3 ±0	2–4
Medial stabilizing line	3 ±1.5	3 ±1.5	2–4
Y-Balance test (YBT)			
Anterior (cm)	63 ±3.3	60 ±1.8	56–67
Posteromedial (cm)	100 ±10.8	98 ±9.5	88–106
Posterolateral (cm)	93 ±7.8	92 ±11	82–103
Composite (cm)	93.1 ±9.2	90.9 ±7.4	82.8–100

Values are expressed as median ± IQR.

Peak Oxygen Uptake (V̇O$_2$peak) was meanly attained at a treadmill velocity of 13 km·h^{-1}; rate of perceived exertion, measured on a 6–20 Borg scale, was marginally lower than 17. Maximal heart rate during the treadmill test reached 190 beats·min^{-1} and 100% of the estimated maximal heart rate. V̇O$_2$peak values were raging between 2.4 and 4.2 l·min^{-1} (median ± IQR: 3.7 ±0.8), and between 46.8 and 59.7 ml·kg^{-1}·min^{-1} (median ± IQR: 51.1 ±4.5).

Because few differences between L and R limbs where found, correlation analyses were computed with a composite value of strength or functional performance tests. Correlating the physiological parameters amongst themselves, handgrip max and mean positively and strongly correlated with lower limb extensor muscles and adductor muscles and with Bt posterior power line and posterior stabilizing line. Firstly, grip strength seems to reflect lower limb strength. Furthermore, handgrip max and mean positively and strongly correlated with peak oxygen uptake. Other correlations between maximal isometric strength and functional performance tests were found for lower limb extensor muscles with Bt posterior power line and posterior stabilizing line. Secondly, trunk and

hip musculature seems to reflect maximal isometric strength of both upper and lower limbs. Lower limb extensor muscles positively and strongly correlated with peak oxygen uptake, too. In general, the strongest athletes had a superior cardiorespiratory fitness. Bt Posterior stabilizing line correlated with peak oxygen uptake. Lastly, no correlations were found between Functional Movement Screen and Y-Balance test and any other physiological parameters (Table 4).

Table 4. Spearman Rank Correlation (rho) for physiological parameters

	Htmax	Htmean	Emf	Amf	Bt PPL	Bt PSL	V˙O$_2$peak
Htmax	1						
Htmean	0.964*	1					
Emf	0.929*	0.964*	1				
Amf	0.786	0.893*	0.857*	1			
Bt PPL	0.929*	0.929*	0.929*	0.857*	1		
Bt PSL	0.813*	0.813*	0.813*	0.563	0.670	1	
V˙O$_2$peak	0.821*	0.857*	0.821*	0.679	0.643	0.813	1

Htmax – Handgrip max, Htmean – Handgrip mean, Emf – Lower limb extensor muscles, Amf – Lower limb adductor muscles,
Bt PPL – Bt Posterior power line, Bt PSL – Bt Posterior stabilizing line.

* $p < 0.05$.

Table 5. Spearman Rank Correlation (rho) for physiological parameters and age, FEI ranking, competition years

	Age	FEI ranking	Competition years
Maximal Isometric Strength			
Handgrip max	0.259	−0.357	0.580
Handgrip mean	0.045	−0.321	0.402
Handgrip decrease	0.348	0.286	0.170
Lower limb extensor muscles	−0.063	−0.107	0.330
Lower limb adductor muscles	−0.116	−0.071	0.241
Functional performance tests			
FMS score	−0.250	−0.473	−0.446
Bt Posterior power line	0.152	−0.071	0.438
Bt Anterior power line	0.571	−0.063	0.696
Bt Posterior stabilizing line	0.196	−0.188	0.321
Bt Lateral stabilizing line	0.027	0.607	0.455
Bt Medial stabilizing line	−0.339	−0.036	0.18
YBT Anterior	0.830*	−0.714	0.545
YBT Posteromedial	0.161	−0.366	−0.071
YBT Posterolateral	0.402	−0.893*	0.259
YBT Composite	−0.188	−0.464	0.027
Peak Oxygen Uptake			
Treadmill velocity	−0.509	−0.313	−0.045
V˙O$_2$peak (l·min^{-1})	0.045	−0.393	0.402
V˙O$_2$peak (ml·kg^{-1}·min^{-1})	−0.580	−0.179	0.134

* $p < 0.05$.

Table 5 showed the Spearman Rank Correlation results between physiological parameters and age, FEI ranking, and competition years. Age moderately correlated with competition years (r_s = 0.679) and strongly correlated with Anterior YBT (p = 0.0420). The oldest athletes had a greater postural control on the anterior direction. FEI ranking moderately correlated with Anterior YBT and strongly correlated with Posterolateral YBT (p = 0.0287). The athletes with a superior standing in the ranking had a greater postural control especially on the posterolateral direction. Only a moderate, non-significant, correlation was found between competition years and Bt Anterior power line. Conversely, maximal isometric strength, and maximal aerobic power did not result correlated with any other measured parameter.

Discussion

The aim of this study was to describe anthropometric and physiological characteristics of prospective Olympics Eventing horse riders and to assess force, balance and functional asymmetry, providing novel informative data for these athletes. Symmetry in ergonomic and functional outlines and relationship between the measured parameters and their International ranking and years of competitions were also assessed.

Functional and asymmetry assessment

Equestrianism has been identified as a sport that requires perfecting the conduct of different means of travel and has been compared to other travel sports such as motor sports and water events (e.g. sailing, yachting) (Bompa, Haff, 2009). It has been elucidated that these 'travel sports' require the development of complex skills that necessitate many hours of training, and as athletes will have to make quick decisions, they involve quick proprioceptive processing. Bompa and Haff (2009) suggest that the dominant motor abilities athletes should possess in these sports are strength, reaction time, balance and endurance.

Subjects presented good maximal (~50 kg) and mean (~40 kg) hand-grip force, with a % force decrease of ~20%, and a statistically significant difference between hands for the latter value. Previous studies on equestrian athletes reported much lower maximal handgrip force (~30 kg or less); however, most researches were conducted on female amateur riders (Meyers, Sterling, 2000). If only female results are taken into account, hand grip strength values of the female riders were in-line with those of the other female athletes (Cronin, Lawton, Harris, Kilding, McMaster, 2017; Roberts et al., 2009). A difference between hands values is commonly reported, even if one study registered a notably higher grip strength on the right hand (Hobbs et al., 2014), while another study registered higher hand grip forces for the left hand for the amateur riders, and comparable values for both hands in elite riders (Sung et al., 2015). The high hand grip force shown by elite equestrian athletes of each gender indicates that the repetitive high-intensity handgrip actions frequently executed during equestrian sessions, over the years of training, may lead athletes to develop good hand grip strength. Furthermore, both lower limb extensors and adductors muscles resulted remarkably stronger when compared with non-athletic subjects (Harbo et al., 2012; Stoll et al., 2000). Even if it is not possible to confirm the cause–effect relationship between training and development of strength performance, the high isometric force values reported in the present study reinforce the suggestion that strength development in elite 'travel sports' athletes can be induced by training on the horse also in the absence of other specific strength training sessions.

Functional performance tests (FPTs) "simulate sport and activity" assessing aspects of performance, functional abilities, and/or the presence of dysfunctional movement patterns (Brumitt, 2015). FMS is described as

an assessment of the quality of human movement for which a score ≤14 has a high specificity for predicting injury; therefore elite riders of our study can be defined as having poor functional abilities with an increased risk of injury or low back pain (Bonazza et al., 2017). Besides, the Bunkie test score of 3.3, accompanied by only two different scores between right and left side, can be considered representative of good core muscular endurance. Since the ability to train the horse to be ambidextrous is considered highly desirable, rider symmetry found in both FMS and Bunkie tests can be recognized as a positive trait (Hobbs et al., 2014). According to YBT, anterior values were significantly higher for the left side, with a large effect, participants exhibiting an anterior reach asymmetry of 3 cm. Previous evidences on the YBT for injury prediction identified that individuals with anterior left/right asymmetries greater than 4 cm on the YBT were 2.5 times more likely to sustain a lower extremity injury (Plisky, Rauh, Kaminski, Underwood, 2006). Therefore, elite riders balance asymmetries resulted lower than values predicting injuries proneness.

V̇O$_2$peak of Eventing elite horse riders was slightly above 50 ml·kg^{-1}·min^{-1}, in line with literature values. Actually, when V̇O$_2$max values are compared between elite, amateur and collegiate/novice riders, the first reach 51–55 ml·kg^{-1}·min^{-1}, while the second cut down at 44–47 ml·kg^{-1}·min^{-1} and the latter restrict to 34–37 ml·kg^{-1}·min^{-1} (Meyers, 2006; Meyers, Sterling, 2000; Sung et al., 2015). It is plausible to think that the regular and intense riding training of elite athletes, who typically ride several horses each day, cantering and jumping with all of them and compete almost every week in multiple phases competitions, seems to elicit much higher cardiovascular fitness than recreational horse riding. Some authors suggested that increased riding exposure may result in positive physiological adaptation among the trained group (Kiely, Warrington, Mcgoldrick, O'loughlin, Cullen, 2019).

Correlations

Correlating the physiological parameters amongst themselves, correlations between maximal strength and functional performance were found. Significant positive relationships between isometric strength tests and the directional reaching of the Y-Balance test were previously reported (Chtara et al., 2018). It has been speculated that a great lower limb isometric strength may allow a better overall dynamic balance performance. However, this latter statement should be checked throughout a training investigation regarding the effect of isometric strengthening on dynamic balance performance. Indeed, no relationships were found between isometric lower limbs muscles force and balance performance in the present study.

As it could be expected competition years was related to age, even though the relationship didn't reach statistical significance (r_s = 0.679). Age significantly correlated with Anterior YBT (p = 0.0420), the oldest athletes having a greater postural control on the anterior direction. Anterior YBT was moderately and non-significantly correlated with competition years. Conversely, maximal isometric strength, and maximal aerobic power did not result correlated with any other measured parameter. FEI ranking moderately correlated with Anterior YBT and strongly correlated with Posterolateral YBT (p = 0.0287). The athletes with a superior standing in the ranking had a greater postural control especially on the posterolateral direction. Since Eventing required a high cardiovascular effort (Roberts et al., 2009), a good aerobic capacity has been suggested to be a factor determining riding performance at competitive level. Nonetheless, in the present study no correlation had been found between maximal aerobic power (V̇O$_2$peak) and performance level (FEI rank), indicating that the combined horse-human partnership adds further complexity and variability to the performance factors, furtherly complicated by the horse having its own free mind.

Conclusions

The assessment of rider's physical characteristics may provide coaches and athletes with a reference physique and may aid in the development of strength and conditioning programs to optimize horses and riders potential and health (Kraus et al., 2014). In the present study, seven male and female prospective Italian Olympic Event riders had high maximal isometric strength, both in the hands and lower limbs, good physical functions parameters and balance and good maximal aerobic power. Even though no general conclusion can be made on such a small sample size, results show that these high-level horse riders attained good physical fitness level over various aspects. Moreover, the lack of important asymmetries between left and right side for muscular strength and balance could suggest that, at such high level of competition, multiple movement qualities and optimal movement patterns are needed. Lastly, results showed that, in this group of elite athletes, oldest horse riders had more years of competition experience and a greater postural control on the anterior direction and that postural control better correlated with FEI ranking, moderately on the anterior direction and strongly with posterolateral balance.

More quantitative measurements of anatomical, functional and dynamical asymmetry compared to ridden postural asymmetries are needed to understand the effects of riding on strength and posture. Due to the large variability between riders, further work should incorporate longitudinal within-rider monitoring, which may indicate better the cause and effect relationships between riding and changes in physical capacity.

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