Artificial intelligence and GPS sensor technology for 3D analyses in the biomechanics of jumping horses

Keywords: horse; jumping, biomechanics, GPS sensor

Autoren: Stéphane Montavon [1], David Deillon [2], Johnathan Bertolaccini [3], Michel Deriaz[3]

1. Veterinary Department of the Swiss Armed Forces, CH-3063 Bern
2. Alogo Analysis SA, CH-1020 Renens
3. Travelling and Mobility Laboratory – University of Geneva, CH-1227 Carouge

Korresspondenzadresse:

Oberst Dr med. vet.
Stéphane Montavon
DVM, Chief of the Veterinary Department, Swiss Armed Forces, Staff, Medical Service, Worblentalstrasse 36, CH-3063 Ittigen, Bern, Switzerland

Conflict of interest: No potential competing interest was reported by the author.

Abstract

Pathologies of the locomotor system in the horse are strongly linked to competition and daily work sessions. In the show jumping horse, repetitive loads and unsuitable surface conditions too often cause serious and potentially career-ending injuries. In this context, the authors wanted to demonstrate the use of a non-invasive sensor integrated in the girth to characterize the important criteria that define good biomechanics in a jumping horse (Alogo Move Pro® Sensor). Based on AI (artificial intelligence) and GPS (global positioning system) sensor technology, this device accurately measures parameters that may help in identifying crucial aspects of jumps relevant either for performance or injury prevention. In a preliminary study, it was possible to qualitatively and quantitatively analyse the three critical phases of a jump sequence, namely approach, jumping parabola and move off. Different parameters were measured for each of these phases. Thanks to state-of-the-art technology used in aeronautical guidance, the sensor allows the display of unique data such as the real trajectory in 3D. A set of analysis algorithms was developed and used. Two objectives, which could be verified in practice, have been formulated. These results were similar and in line with previously published data by other authors.

Abstract

Pathologien des Bewegungsapparates beim Pferd sind stark mit dem Wettkampf und der täglichen Arbeit verbunden. Beim Springpferd führen repetitive Belastungen und ungeeignete Bodenverhältnisse oft zu schweren und möglicherweise karrierebeendenden Verletzungen. In diesem Zusammenhang wollten die Autoren die Verwendung eines nichtinvasiven, in den Sattelgurt integrierten Sensors demonstrieren, um die wichtigen Kriterien zu charakterisieren, die eine gute Biomechanik bei einem Springpferd definieren (ALOGO Move Pro Sensor). Basierend auf AI (Artificial Intelligence) und GPS-Sensortechnologie (Global Positioning System), misst dieses Gerät akkurat Parameter, die helfen können, entscheidende Aspekte der Sprünge zu identifizieren, die entweder für die Leistung oder die Verletzungsprävention relevant sind. In einer Vorstudie war es möglich, die drei kritischen Phasen einer Sprungsequenz, nämlich Anlauf, Absprungparabel und Landung, qualitativ und quantitativ zu analysieren. Für jede dieser Phasen wurden unterschiedliche Parameter gemessen. Dank modernster Technologie, die in der Flugführung eingesetzt wird, erlaubt der Sensor die Darstellung einzigartiger Daten, wie z. B. der realen Flugbahn, in 3D. Es wurde eine Reihe von Analysealgorithmen entwickelt und eingesetzt. Es wurden zwei Ziele formuliert, die in der Praxis verifiziert werden konnten. Die Ergebnisse waren ähnlich und stimmten mit bereits veröffentlichten Daten anderer Autoren überein.

Introduction

The training of sport horses is of great and growing interest as pathol-ogies of the locomotor system are closely related to competition and to the structure of daily training sessions. In the show jumping horse in particular, these injuries are often caused by repetitive loads and unsuitable surface conditions [1, 2].

It is also confirmed that the importance of training regimens for orthopedic health in show jumpers is preponderant. Repetitive overload injury is a major problem for sport horses of any discipline and causes specific lesions for different equestrian sports [2]. Riders at an elite professional level of show jumping use training regimens that vary substantially in time spent training and other physical activities. Show jumping horses competing at the same level are challenged differently during training. Activities such as working on the flat or obstacle training are too often repetitive and not sufficiently diversified. The equestrian infrastructure and quality of the surfaces are not always in line with the level of demands required for top-level sport [1].

Numerous scientific studies exist[3–5] describing the biomechanics of the show jumping horse and rider over different types of obstacles. The most important results of the kinematic and kinetic investigations are the take-off position, the acceleration of the hind limbs (leading- and trailing hind limb) at take-off as well as the load of the fore limbs (leading- and trailing fore limb) at landing. Furthermore, Clayton[6] divided the movement process while jumping in five phases: approach, takeoff, suspension, landing and move off. The approach consists of a series of strides, which are counted retrospectively, backwards from the fence. The subsequent jumping strides include the takeoff of the hind limbs as well as suspension and landing of the fore limbs. After landing of the fore limbs, the horse moves off in canter.

Clayton and Barlow[7] investigated the approach to a 1.55 m high vertical fence. The closer the horse gets to the obstacle, the shorter the distance, duration and ground speed of the stride. The combination of these three factors leads to the kinetic energy required to realize a good takeoff.

Some authors[7,8] demonstrate the ideal distance from the obstacle in relation to the height of the fence. Moreover, a good distance for the takeoff allows all joints and muscles to develop an ideal parabola throughout the jump.

The flying phase (also called suspension phase or airborne phase) takes time and is dependent on the height of the obstacle[3]. The taller the height, the longer the suspension phase. The same applies to the length of the jump: the higher the obstacle the longer the length of the jump. This applies both to vertical obstacles and oxers. The duration and length of the suspension phases are longer on oxers than on vertical obstacles.

Similarly as for takeoff, the leading forelimb at landing is in contact with the ground for longer[9] than the trailing forelimb. The load on the forelimbs at landing increases for higher obstacles[7].

It is important to correlate the different locomotor pathologies with the biomechanics of show jumping to know, both in training and in competition, when the demands are high and how they are expressed. It is also important to do everything possible in terms of prevention to ensure the physical and mental well-being of sport horses, thus also avoiding high veterinary costs.

In this context, new technologies will play an important role in the biomechanical description of the jumping movement.

The aim of this study is to show an example of a new technology that can provide new indications on the biomechanical criteria of jumping during the various jumping phases, especially the flying phase.

The device from ALOGO Move Pro® (*www.alogo-analysis.com*) a unique sensor integrated in a strap with high technology was chosen (Figure 1). It contains an IMU (inertial measurement unit), an accelerometer, a magnetometer and a goniometer. It allows the visualization and analysis of jumps, to identify optimal parameters to improve them and to detect variations in locomotion in order to prevent any form of injury. The precision allows the tracking of the horse's movement in a 3D space. It also detects lateral balance, straightness, cadence, speed and duration of a session (Figure 2). Its functionalities are designed to measure the actual trajectory of the jump, including the approach, the takeoff, the suspension, as well as the landing and the move off phases. Height and length are measured for each jump and stride. Angular measurement and calculation of striking power is performed for each jump and stride at takeoff.

Two objectives were set for this study: firstly, to verify biomechanical values measured with this sensor in the field of show jumping compared to measurements published by other authors and secondly, to obtain new data provided by a new technology.

Materials and methods

Four horses belonging to the Swiss Armed Forces were used, ranging between 5 and 11 years old. Their level of training was that of a military service horse, capable of correctly riding a 1.20 m course with a rider licensed with the Swiss Equestrian Federation (www. fnch.ch). Their heights at the withers ranged from 163 cm to 176 cm. All the horses were sound, shod correctly and fit for (military) service. The test surface consisted of a 20 m × 60 m well-drained silica sand arena.

Each horse was examined succinctly for the possible appearance of lameness. All the horses were ridden by the same, experienced rider in order to reduce the influence of riding skills. The positioning of the sensor in the strap was checked. The central position on the girth was finalized once the horse was definitively strapped in and ready to jump.

Two obstacles were placed on the middle line at a distance of 21 m, a classic 5 stride distance. The obstacles were jumped at heights of 0.80 m, 0.90 m, and 1.00 m up to 1.10 m. Each horse performed the lines on each hand, varying the following sequence: vertical/oxer and oxer/vertical. These sequences are shown in figure 3.

The name of the strides has been defined as follows: the stride before the first jump F1 (approach), the jump on the first obstacle F2 (takeoff, suspension and landing), the stride after the first jump F3 (move off), the following strides F4, F5, F6 as normal strides between two fences, the stride before the second jump F7 (approach), the jump on the second obstacle F8 (takeoff, suspension and

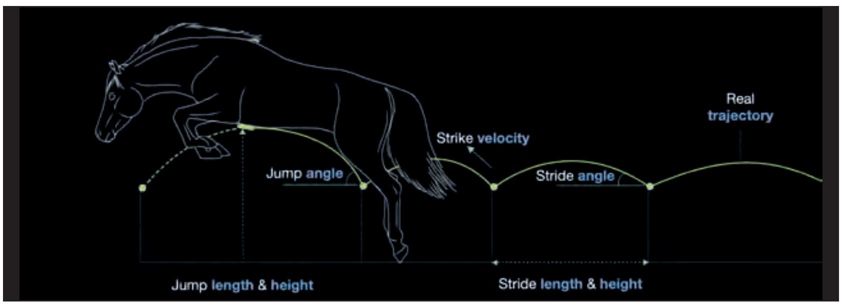

Figure 2: *ALOGO measured criterias*

Figure 1: *The ALOGO Move Pro Sensor*

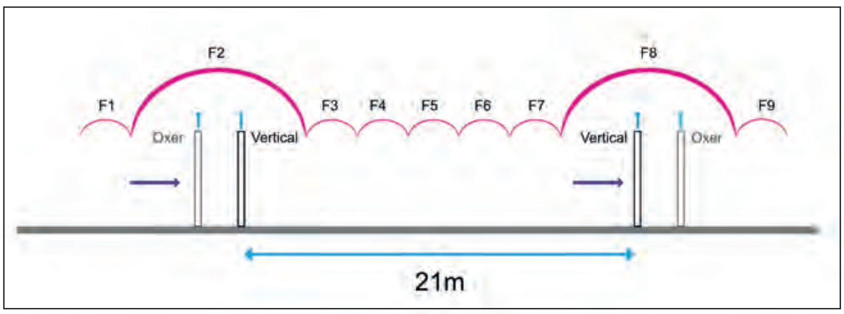

Figure 3: *ALOGO – design experience diagram*

landing), the stride after the second jump F9 (move off) (figure 3). Each horse crossed the same line 12 times (6 times on the left hand and 6 times on the right hand). A total of 48 (N = 48) crossings were therefore recorded. The order of the passages was as follows: one passage on a vertical at 0.8 m and one oxer at 0.9/0.9 m (left and right hand). A second passage on a vertical at 0.9 m and an oxer at 1.0/1.0 m (left and right hand). A third passage on a vertical at 1.0 m and an oxer at 1.10/1.10 m (left and right hand). A fourth passage on an oxer at 0.8/0.8 m and a vertical at 0.9 m (left and right hand). A fifth passage on an oxer at 0.9/0.9 m and a vertical at 1.0 m (left and right hand). A sixth passage on an oxer at 1.0/1.0 m and a vertical at 1.10 m (left and right hand).

With the ALOGO Move Pro® sensor the following parameters were measured: acceleration in m/s^2, velocity (speed) in m/s, length measured in m, height measured in m – height in this experiment model is the place where the sensor is attached (under the girth), angle of jump measured at the position of the sensor in degrees. The ALOGO Move Pro® sensor was fixed at the girth and centered in the middle as shown in figure 4.

All data were analysed using R development Core (2008) Version 3.2.3. (*www.R-project.org*) in order to verify our objectives and their significance. The results were collected and analysed for 3 phases of each jump, i. e. the approach phase (F1 and F7), the flying phase (F2 and F8) and the move off phase (F3 and F9). The means and standard deviations were also calculated.

Results

Results are shown in table 1: In order to obtain a representative average of the five criteria (acceleration, velocity, length, height and angle in degree), the results were gathered for the three phases of the jump (approach, flying and move off) and for all four horses used.

During the approach phase, it was possible to demonstrate a mean acceleration (35.62 m/s^2 or 3.63 G) and a mean velocity (6.0 m/s). The mean length of the stride before takeoff was short (2.93 m). The mean height of the stride reflecting the position of the CG (Center of Gravity) was low (0.14 m). Finally, the mean inclination of the horse measured through the angular value of the limbs and the trunk was also low (3.48 degrees).

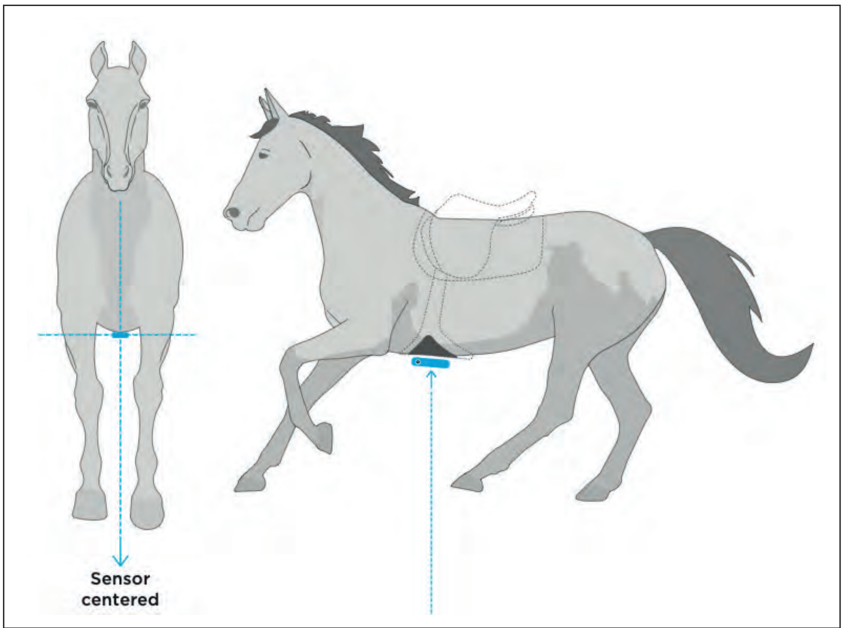

Figure 4: *Positioning of the ALOGO Sensor*

The flying phase is, as described above, the combination of the takeoff, suspension and landing. Compared to the approach phase, the mean acceleration (54.62 m/s^2 or 5.56 G) was significantly higher ($p < 0.01$) and the mean velocity was smaller (5.00 m/s). The mean length of the jump (4.76 m) was significantly bigger ($p < 0.01$) than the length of the approach stride. The mean height of the jump (1.32 m) reflects the height of the fence plus the height of a normal stride. The mean inclination of the horse measured through the angular value of the limbs and the trunk was very high during takeoff (29.9 degrees) demonstrating the transformation of kinetic energy to potential energy. This inclination is significantly higher than during the approach ($P < 0.01$).

The move off phase was characterized by a smaller mean acceleration (38.05 m/s^2). The mean velocity after the jumping phase logically increased (6.35 m/s). The mean length (3.65 m) and height (0.06 m) was also significantly shorter and smaller than during the jumping phase ($P< 0.01$). The same applies for the mean inclination of the horse (9.3 degrees) measured through the angular value of the limbs and the trunk. The mean inclination during the move off phase was significantly higher than during the approach phase ($P<0.05$).

The results allowing the analysis of the various objectives formulated are found in table 2.

Discussion

Based on the results obtained in our preliminary study and using fences with heights and widths not exceeding 1.10 m, there were statistically no differences for the analysed criteria within the three phases of the jump (approach, suspension and move off) between a vertical and an oxer. The height and width of the obstacles seem to play a minor role in the different criteria measured. Obtained values for acceleration, velocity, length and height of strides as well as angles of strides and jumps are within the different phases similar at heights up to and including 1.10 m. The parable of the jump seems not to differ for all the criteria analysed between a vertical obstacle or an oxer, and this applies to all different heights used; it might therefore appear that the horse does not know the difference between a vertical and an oxer and that jumping at these heights is simply a canter stride greater than another. These figures are confirmed by other authors [6], and this argument is also noted by trainers and experienced riders. The values measured during the different sequences of the jump are coherent and allow the logical detailing of the different analysed phases. The acceleration criterion revealed interesting values in m/s^2 which, converted to G, provide a good reflection of the forces exerted on the hind limbs especially at the time of takeoff. It is particularly interesting to note the very small mean height of the stride following the jump (0.06 m), which corresponds to the move off phase ($P < 0.05$). This very small height can be explained by the fact that the horse has to recover its own balance in order to be ready for the approach phase to the next fence. The choice to use only four horses for the study was dictated by the availability of military horses at that time. Consistency of these values with previously published studies shows that the device is reliable and efficient. Only the values measured during acceleration are new and will be interesting to investigate further in future experiments. A full validation procedure of the device must and will be performed. The veterinary service of the Swiss Armed Forces in partnership with the University of Zürich (Abteilung für Sportmedizin) has been mandated for this purpose.

Conclusions

Authors were able to test the use of the ALOGO Move Pro® sensor in practice. A scientific protocol allowed us to verify the various functionalities such as length, height and velocity of strides in the approach, flying and move off phases. Acceleration and inclination at the takeoff phase are new values that this technology allows us to measure. We were able to compare the values obtained and found them to be in line with data previously published by other experienced authors. Correspondence with these authors allowed for these comparisons. The credibility and reliability of this sensor augurs new areas of research in the field of biomechanics of the show jumping horse, helping to diagnose lameness or irregularities that are difficult to detect with the naked eye. •

	Approach: F1 + F7	**Jump: F2 + F8**	**Move off: F3 + F9**
	mean	mean	mean
Acceleration in m/s^2	35.62 (SD= 7.14)	54.62 (SD= 13.46)	38.05 (SD= 8.15)
Velocity in m/s	6.00 (SD = 0.64)	5.00 (SD = 0.64)	6.35 (SD = 0.58)
Length in m	2.93 (SD = 0.5)	4.76 (SD = 0.86)	3.65 (SD = 0.33)
Height in m	0.14 (SD = 0.04)	1.32 (SD = 0.13)	0.06 (SD = 0.02)
Stride / Jump angle in degree	3.48 (SD = 2.81)	29.9 (SD = 5.82)	9.3 (SD = 2.80)

Table 1: *ALOGO Move Pro – collected results*

Hypothesis and their statistical differences	Significance
Significance: * = $p < 0.05$ **= $p < 0.01$ – n. s. = not significant	
Acceleration in m/s^2	
Acceleration during the flying phase is much bigger than during approach and move off phases	**
Acceleration during the move off phase is bigger than during the approach phase	*
Velocity (Speed) in m/s	
Velocity during the flying phase over the two fences	n. s.
Velocity during the approach and move off phases is much higher than during the jumping phase	**
Velocity during the move off phase is higher than during the approach phase	*
Length in m	
Length during the flying phase is bigger than during the approach and move off phase	**
Length during the approach phase is much smaller than during the flying and move off phase	**
Height in m	
Height during the flying phase is much bigger than during the approach and move off phase	**
Height during the move off phase is smaller than during the approach phase	*
Stride / Jump angle in degree	
Angle during the flying phase is much bigger than during approach and move off phase	**
Angle during the move off phase is bigger than during the approach phase	*

Table 2: *ALOGO Move Pro – Hypothesis and their statistical differences*

Referenzen

1. Lönnell AC, Bröjer J, Nostell K, Hernlund E, Roepstorff L, Tranquille CA, Murray RC, Oomen A, van Weeren R, Bitschnau C, Montavon S, Weishaupt MA and Egenvall A. Variation in Training Regimens in Professional Show jumping Yards. EVJ. 2014; 46: 233–238.

2. Egenvall A, Tranquille CA, Lönnell AC, Bitschnau C, Oomen A, Hernlund E, Montavon S, Franko MA, Murray RC, Weishaupt MA, van Weeren R, Roepstorff L. Days lost to Training and Competition in relation to Workload in 263 Elite Show-jumping Horses in four European Countries. PVM. 2013; 112: 387–400.

3. Falaturi PH, Reiniger EF, Preuschoft H. Bewegungsanalyse bei Springpferden mit Hilfe der Computerkinematographie. Pferdeheilkunde. 2001; 17:361–368.

4. Clayton HM, Hobbs SJ. The role of biomechanical analysis of horse and rider in equitation science. Applied Animal Behavior Science. 2017; 190: 123–132.

5. Fercher C. The biomechanics of movement of horses engaged in jumping over different obstacles in competition and training. JEVS. 2017; 49: 69–80.

6. Clayton HM. Terminology of the description of equine jumping kinematics. JEVS. 1989; 9: 341–348.

7. Clayton HM, Barlow DA. Stride characteristics of four Grand Prix jumping horses. Equine Exerc Physiol. 1991; 3: 151–157.

8. Van den Bogert AJ, Janssen MO, Deuel NR. Kinematics of the hind limb push off in elite show jumping horses. Equine Vet J Suppl. 1994; 17: 80–86.

9. Meershoek LS, Schamhardt HC, Roepstorff L, Johnston C. Forelimb tendon loading during jump landings and influence of fence height. Equine Vet J. 2001; 33: 6–10.

Schweizerische
Gesellschaft der Offiziere
der Sanitätstruppen (SGOS)

Société suisse des officiers
des troupes sanitaires (SSOTS)

Società svizzera degli ufficiali delle
truppe sanitarie (SSUTS)

1 | 2021

AUSGABENTHEMA

COVID-19-Pandemie

SWISS REVIEW OF MILITARY AND DISASTER MEDICINE
SCHWEIZERISCHE ZEITSCHRIFT FUER MILITAER- UND KATASTROPHENMEDIZIN
REVUE SUISSE DE MEDECINE MILITAIRE ET DE CATASTROPHE

Jahrgang: 99
ISSN: 1660-9514

Impressum

Swiss Review of Military and Disaster Medicine (SRMDM) ist eine Zeitschrift der Schweizerischen Gesellschaft der Offiziere der Sanitätstruppen (SGOS).

Jahrgang: 99
ISSN: 1660-9514
Ausgabe: 1 | 2021
Visuelles Konzept: Mosaiq Kommunikationsagentur, Egerkingen
Druck: Impress Spiegel AG, Egerkingen