Observation as a Tool for Gait Assessment: Eye, Camera, Vision and Viewing

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Keywords: Kinematics, Gait Analysis, Photography, Two-Dimensional Motion Analysis, Perception, Education.

Abstract: The aim of this research was to analyse observation skills through the assessment of human gait. The hypothesis was that the observation of human gait, in the way experienced practitioners do, would not provide sufficient results among novice students. The study was conducted retrospectively using the data collected during Clinical Kinesiology course, in the first semester of the academic year 2020/2021 via on-line seminars. A total of 190 first-year bachelor level physiotherapy students (120 female and 70 male) participated in the study (90 full-time and 100 part-time). Within formulated protocol (i.e., defining the gait cycle and its eight phases), each student made a video recording of a normal walk, in the sagittal plane, according to the left-to-right convention. In the second and third timepoints, everyone watched a recording of one subject, made in laboratory. Best average result was in the evaluation of the change between the fifth (pre-swing) and the sixth (initial swing) phases in the knee ($\bar{x}$ = 88.24%), and the best absolute result (100% correct) was achieved in the 2nd and 3rd measurement point, between the second (loading response) and third (mid stance) phase in the hip (average result of all timepoints for that change $\bar{x}$ = 82.45%). The worst absolute result (10%) occurred: 1) in the change between the first (initial contact) and second (loading response) phases in the hip, and 2) in the change between the third (mid stance) and fourth (terminal stance) phases in the ankle, both in the 2nd measurement point. Students generally did not accurately assess the human gait (from the initial 43.96%, through 61.95%, to the final 62.45% distribution of correct answers), in the observational way that experienced experts do in their clinical practice, due to observational obstacles – perceptive and cognitive. Technology-free approaches are commonly used in clinical practice due to their simplicity and affordability. However, these are subjective methods, and the gap should be bridged with an objective assessment approach, e.g., video-based, or computerized 2D/3D motion analysis.

1 INTRODUCTION

Observation, along with palpation, is the main tool in the clinical work of a physiotherapist. In observation, the precision and experience of the examiner is very important. This is why such a skill should be taught from the very beginning of formal education at the university level. In the curriculum, in the Clinical Kinesiology course, as well as in the Biomechanics and Applied Biomechanics courses, human gait analysis is fundamental. Although there are many options for gait analysis (kinematic, kinetic, electromyographic), in a clinical sense, kinematic observational movement analysis, i.e., combined complex open and closed kinematic chain movements such as gait, is usually performed visually. Therefore, a well-experienced "eye" is needed. When a patient enters a physiotherapist's office, the presentation of gait is often the first step in discovering the causes and consequences of pathology, imbalances, irregular movement patterns, etc., which are masked in conventional static postural analysis or diagnostic approaches that are also static (e.g., MR, X-ray, or CT). The question is whether the observation is accurate enough in clinical practice or whether we have to use instrumented biomechanical analysis (e.g., methods and systems of optoelectronic gait analysis) for a proper assessment.

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Various automatic imaging measurement techniques using special purpose hardware have been developed (Mihradi et al., 2013). Biomechanical analysis of human gait using an optical tracking system has been widely applied to assess and diagnose various pathologies, monitor rehabilitation methods, and analyse sports techniques (Flores-Morales et al., 2016). Optical motion capture is an established tool for assessing biomechanics. Using standard laboratory equipment ensures the simplicity of the procedure and its wide applicability (Eichelberger et al., 2016). Despite this, such systems have been used in controlled environments, limited by the research area, with limitations on the mass of the equipment and the costs of its implementation (Flores-Morales et al., 2016).

Toister (2020) differentiates between two different types of experience: vision and viewing. He explains that vision can be defined as a situation where similar modes of perception are enabled for most events in the real world. Viewing, on the other hand, he explains as a situation that allows the time required for the cognitive processes of vision to be separated from the time span of events in the real world.

Famous painting *Horse-racing at Epsom*, 1821, oil on canvas, 92 x 122.5 cm (Figure 1) exhibited in the Louvre, Paris, was made by the great nineteenth-century French painter Théodore Gericault. Although he was initially a neoclassicist (i.e., inclined to resemble and even magnify real anatomy) (Davies et al., 2010), he showed horses with outstretched legs in full flight through the air (Gombrich, 2004). It is so common sense, dos Santos (2009) points out, that horse legs position is obviously not true, adding that the real position is non-intuitive and intangible, made conceivable only through an instrument.

Figure 1: *Horse-racing at Epsom*, by Théodore Gericault (1821).

The introduction of technologies that improved observation (e.g., the *camera obscura*, the telescope, the zoopraxiscope), made it possible to create images that were dissociated from the tangible and began to define the real state. A paradigmatic example is Eadweard Muybridge's late nineteenth-century pioneer study of horse locomotion (Figure 2). It showed that horses never fully extended their limbs forward and backward, while their hooves were leaving the ground, as previous illustrators such as Gericault had been deceived into interpreting (dos Santos, 2009). Mastandrea and Kennedy (2018) tested images of horse gaits, including analysis of Gericault's image. The authors concluded that it is unrealistic, supporting their conclusion with the description of fake-gallop horse motion: In a jump, the front limbs are flexed at the beginning, and as the horse clears the fence. Then they stretch out, reach towards the ground, and the back extremities bend forward and under the body. The authors state that these findings are consistent with those by Eadweard Muybridge in 1878. Due to the fast movement, it is not possible to make an accurate analysis of the movement by direct perception of galloping horses. Mastandrea and Kennedy believe that this perceptual problem can be solved with the help of stopped-motion photography. On the other hand, at the time Muybridge's photographs were created, they received a cool response from artists, other photographers and certainly the public. The photos were claimed to be "unnatural" and even "unrealistic" (Toister, 2020).

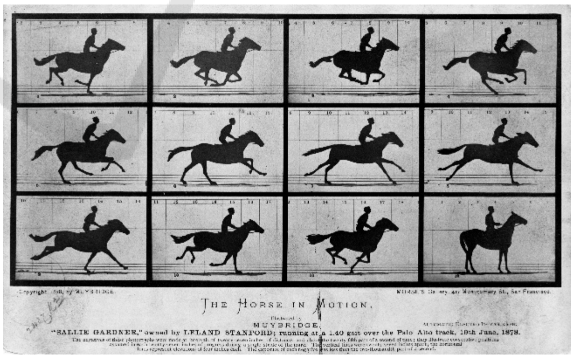

Figure 2: *The horse in motion*, by Eadweard Muybridge (1878).

The aim of this research was to check observation skills on a sample of absolute beginners, through the assessment of human gait, and to find out how effective the kinematic viewing analysis is, or whether there is a need for an instrumented biomechanical approach.

The hypothesis was that the observation of human gait, in the way experienced practitioners do, would not provide sufficient results among novice students.

2 METHODS

2.1 Design

The study was conducted retrospectively using the data collected during Clinical Kinesiology course, in the first semester of the academic year 2020/2021 via on-line seminars (i.e., it was the time of Covid-19 pandemic restrictions), where Moodle e-learning platform and Microsoft Teams software were used.

2.2 Participants

A total of 190 first-year bachelor level physiotherapy students (120 female and 70 male) participated in the study. There were 90 full-time students, and 100 part-time students.

2.3 Procedure

The seminars included three complementary tasks, through which three measurement points were completed.

2.3.1 First Measurement Point

The first seminar began with an introductory online 30-minute lecture on gait analysis via Microsoft Teams. After the theoretical part on the kinesiology analysis of gait (i.e., defining the gait cycle and the eight phases of gait), followed the guidelines for the preparation of homework. Each student had to choose any person (exclusion criteria were choosing themselves or any of their colleagues, the presence of any pathology, such as neuromuscular disorders), and make a video recording of a normal walk (i.e., using normal walking speed without speeding up or slowing down), in the sagittal plane, according to the left-to-right convention. A blind experiment was ensured by the suggestion of using a specific shot that shows only the pelvic area and the lower extremities. The PowerPoint template for creating the homework was uploaded to the Moodle e-learning platform. For each of the eight phases of the walking cycle, in the mentioned PowerPoint template, there was a place for a photo that the students had to extract from the video material, so that each of the eight photos represents a specific phase of the walking cycle. The next task was to quickly change the PowerPoint slides to create an animation (i.e., motion) of the walking cycle, and visually detect 7 changes (I – VII) between 8 postures (e.g., the change between the first (initial contact) and the second (loading response) phase is assigned as change number I, the change between the second (loading response) and third (mid stance) phase is assigned as change number II, etc.), and fill in the table (Table 1), using the symbols F (for flexion), E (for extension) or X (in case there is no change in angle between phases).

Table 1: Seven changes between the eight phases of the gait cycle in the lower limb joints.

	I	II	III	IV	V	VI	VII
Hip							
Knee							
Ankle							

The learning material (a PowerPoint document with a recorded audio guide and detailed information about the homework) was uploaded to the Moodle e-learning platform, and five days were provided for the task. Students had to enter the observed changes in the table. The tasks had to be posted on the Moodle forum (i.e., a PowerPoint document as an attachment to the discussion on the forum), which was set in the form of questions and answers, which means that the insight into the answers of other participants was only possible after the task was submitted. It was possible to submit the material only once.

2.3.2 Second Measurement Point

We started the second task a week after the first one, live online, via the Microsoft Teams interface. The new task was for everyone to observe the same test subject (via the photos extracted from the supplementary materials of the book by Oatis (2009), the recommended literature for the Clinical Kinesiology course). The lecturer was changing the slides at a moderate speed to create an animation. After the end of the last phase, he went through all the gait cycle phases once more, but faster, so that the students could check and finalize their answers. The instructions to the students were to enter the results they recorded while watching the presentation into a word document "Table" (see Table 1) and post the completed document as an answer to the discussion on the new forum. It was possible to submit the material within 30 minutes.

2.3.3 Third Measurement Point

The final task was carried out on the same day, 60 minutes after the second one. The final PowerPoint document was uploaded to the Moodle e-learning platform and was to be filled in by drawing lines connecting the prominent anatomical points for each of the 8 postures (8 phases of the gait cycle) while visually determining the 7 angle changes (by animation – rapid change of slides) for each joint. As in Ross et al. (2015), joint angles were estimated by selecting the following anatomical locations digitally: iliac crest, greater trochanter, and lateral femoral condyle formed the hip joint angle; and greater trochanter, lateral femoral condyle, and lateral malleolus formed the knee joint angle. Students were instructed to assess the ankle joint angle by drawing the line between the lateral tibial condyle and the lateral malleolus, and then distally a line from the lateral malleolus to the head of the fifth metatarsal bone. The students should have entered the results in the table on the last slide of the PowerPoint document and published the material solved in this way as a response to the discussion on the final forum. Additional five days were provided for this final task.

Results based on Perry et al. (1996) are presented in Table 2, and were shown to the students at the next seminar, after a week. In the meantime, they could compare their solutions to the third task with the solutions of other colleagues via the forum.

Table 2: Correct answers (adapted from Perry et al. (1996)).

	I	II	III	IV	V	VI	VII
Hip	X	E	E	F	F	F	X
Knee	F	E	X	F	F	E	E
Ankle	F	E	X	F	E	E	X

2.3.4 Data Reduction

The data were exported to Microsoft Excel, where a comparison of the correct answers was made. The main quantitative data analysis was performed using a frequency analysis.

2.4 Statistical Analysis

All statistical analyses were performed using STATISTICA v.14 (StatSoft, Inc., Tulsa, OK, USA).

3 RESULTS

Based on the frequency analysis of data on the answers of 190 first-year students of physiotherapy, in the Table 3 we have listed the percentages of their correct answers according to gait phases and measurement points.

Figure 3 presents main results on the proportion of correct answers through three measurement points, on average, and for each of the three observed joints.

On average, the differences between the 1^{st} and the other timepoints are obvious, in the direction of better results (from the initial 43.96%, through 61.95%, to the final 62.45%); however, between 2^{nd} and 3^{rd} timepoint there was almost no change.

Trends in the hip and knee are ascend between the initial and second measurement points (initial average 39.54% and 2^{nd} timepoint 63.61% for the hip, and 48.19% to 77.67% for the knee). There is a noticeable difference between these points, while the difference between the 2^{nd} and 3^{rd} measurement points is insignificant for both joints (an increase of 2.79% for the hip and a decrease of 0.61% for the knee). For the assessment of the ankle joint, the results were quite the same for all timepoints (44.13% in 1^{st}, 44.58% in 2^{nd}, and 43.91% in 3^{rd}).

Table 3: Percentages of the students' correct answers for the seven changes between the eight phases of the gait cycle in the lower limb joints.

		I	II	III	IV	V	VI	VII
HIP	First timepoint	15.26	47.36	50.52	21.05	44.73	69.47	28.42
	Second timepoint	10.00	100.00	91.05	38.42	88.94	90.00	26.84
	Third timepoint	15.78	100.00	92.10	37.36	92.63	90.52	36.31
KNEE	First timepoint	31.05	44.73	42.63	57.36	78.94	30.52	52.10
	Second timepoint	76.84	93.15	72.10	94.73	90.52	24.21	92.10
	Third timepoint	78.42	91.05	58.94	94.73	95.26	25.26	95.78
ANKLE	First timepoint	58.42	29.47	51.57	48.94	47.89	30.00	42.63
	Second timepoint	38.42	60.52	10.00	65.78	57.36	53.15	26.84
	Third timepoint	33.68	55.78	12.63	64.73	62.10	54.21	24.21

Legend: I – the change between the first (initial contact) and the second (loading response) phases; II – the change between the second (loading response) and the third (mid stance) phases; III – the change between the third (mid stance) and the fourth (terminal stance) phases; IV – the change between the fourth (terminal stance) and the fifth (pre-swing) phases; V – the change between the fifth (pre-swing) and the sixth (initial swing) phases; VI – the change between the sixth (initial swing) and the seventh (mid swing) phases; VII – the change between the seventh (mid swing) and the eight (terminal swing) phases.

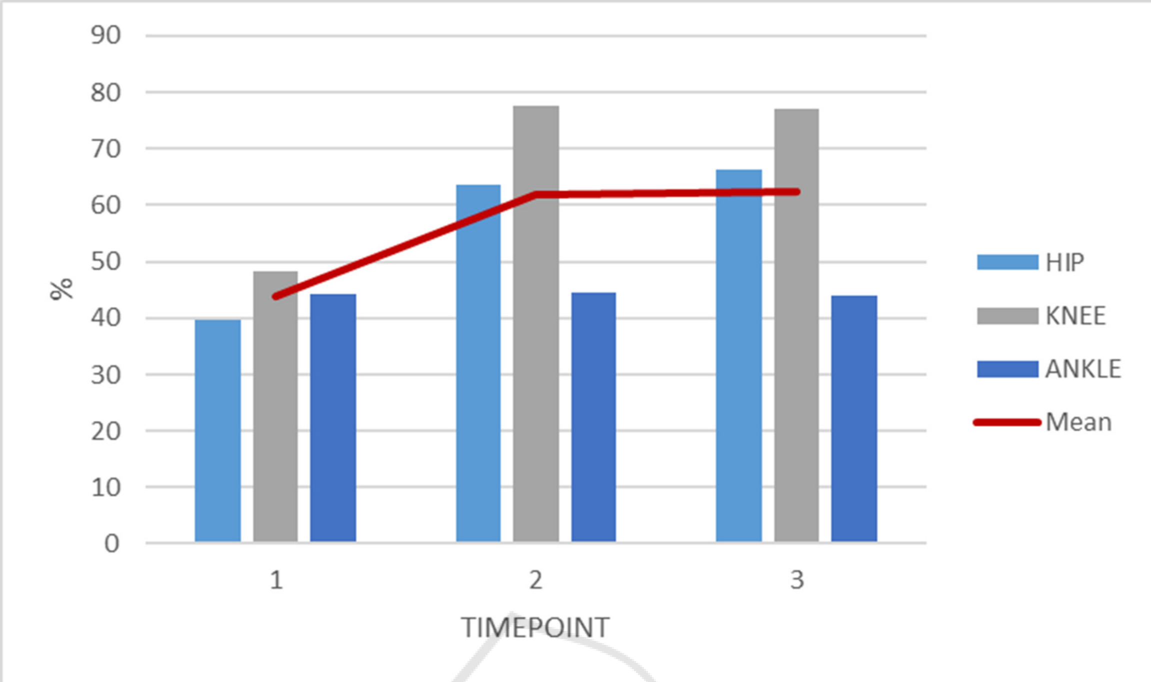

Figure 3: Main results on the proportion of correct answers through three measurement points.

The worst mean assessment result for the hip was the change between the first (initial contact) and the second (loading response) phases ($\bar{x}$ = 13.68%). For the knee, on average, the assessment of the change between the sixth (initial swing) and seventh (mid swing) phases was the least accurate ($\bar{x}$ = 26.66%). The worst average result for the ankle was shown by the evaluation of the change between the third (mid stance) and fourth (terminal stance) phases ($\bar{x}$ = 24.73%).

Figure 4: Observational analysis of the change between the third (mid stance) and the fourth (terminal stance) phase in ankle; the second measurement point.

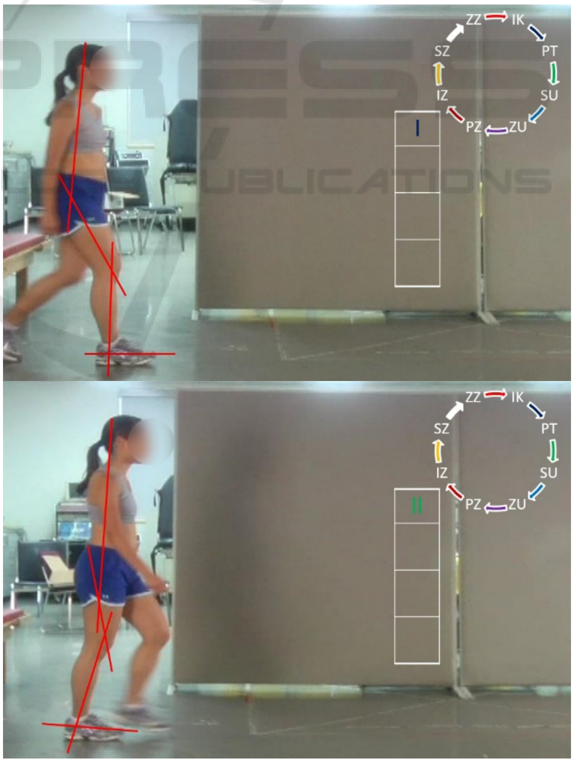

Figure 5: Observational analysis of the change between the second (loading response) and the third (mid stance) phases in hip; the third measurement point.

The worst absolute result was 10% (which means that only one in ten students saw that there was no change in the angle between the proximal and distal segments between the two phases), and this happened in two cases: in the second measurement point of the change between the first (initial contact) and second (loading response) phases in the hip, and in the second measurement point of the change between the third (mid stance) and fourth (terminal stance) phases in the ankle (Figure 4).

On the other hand, the best average result was in the evaluation of the change between the fifth (pre-swing) and the sixth (initial swing) phases in the knee ($\bar{x}$ = 88.24%), and the best absolute result was 100% correct, achieved in the 2nd and 3rd timepoint of observation of the change between the second (loading response) and third (mid stance) phase in the hip (Figure 5), with the average result of all timepoints for that change $\bar{x}$ = 82.45%.

4 DISCUSSION

In this study, we examined the ability and skill of first-year students in observational kinematic gait analysis.

The hypothesis was confirmed: the students generally did not accurately assess the human gait (from the initial 43.96%, through 61.95%, to the final 62.45% distribution of correct answers), in the observational way that experienced experts do in their clinical practice.

To draw a parallel with the academic environment, for this task the students received an average grade of "Sufficient 2", the lowest passing grade (i.e., to pass the exam, 60% correct answers are required). However, this was only achieved at the second and third timepoints; on average, they initially failed. The lack of better results at the last two timepoints, along with the lack of progress between them, can be interpreted as insufficient knowledge and skills of the students, but mainly in the context of observational obstacles – perceptive and cognitive. In a way, the students fell into the same trap that Théodore Gericault had found himself in 200 years earlier. Toister (2020) interprets such obstacles as the temporal incompatibility of photographic technology, where viewing is certainly a non-participatory experience, unlike live viewing or observation in which the observer is also a participant.

Technology-free approaches, such as observational gait analysis, are commonly used in clinical practice due to their simplicity and affordability. However, these are highly subjective methods, where the assessment results depend on the interpretation skills and experience of the clinician (Michelini et al., 2020). This gap should be bridged with an objective assessment approach, e.g., video-based two-dimensional (2D) motion analysis or computerized three-dimensional (3D) motion analysis. Some of the answers to the question of why the students were so imprecise in their observational assessment could be found in article by Toister (2020), where he contextualizes that there are many anatomical reasons for rejecting the comparison between the eye and the camera (e.g., people have two eyes and not one; human eyes are never fixed and are always moving; neurological and cognitive abilities are important for the perception of depth and movement in the human vision, and the camera does not offer anything similar to the above capabilities). Toister (2020) concludes that human vision is more similar to videography than photography, if at all.

The results of the assessment were the best for the knee joint in all three levels of measurement. The reason could be that the knee is the easiest to observe due to its greatest range of motion. Ross et al. (2015) also determined that the results of the testers' knee joint assessment are closest to normal values, while the results they obtained for the hip joint and especially the ankle are not promising.

The students had the most difficulties in detecting cases where there is no change in angle between phases (e.g., the second measurement point of the change between the first (initial contact) and second (loading response) phases in the hip, and the second measurement point of the change between the third (mid stance) and fourth (terminal stance) phases in the ankle. This means that because observers noticed the femur shifts backwards, 70% of them (N = 136) thought they were seeing extension, forgetting that at the same time the pelvis and torso continued to move forward (or went to the right, speaking in a two-dimensional way; as Toister (2020) points out, our field of vision is elliptical and not enclosed in a rectangular frame), leaving hip angle unchanged between the two phases. Similarly, visual detection of heel-off (see Figure 4), led more than 50% of assessors (N = 97) to be sure they saw (plantar) flexion. However, the point is that they missed that both segments moved from phase to phase and their relationship to each other did not change (i.e., the ankle angle remained the same).

It is not that the students are not able to recognize if there is no change between two segments (e.g., there were 72.1% (N = 137) correct answers in the second measurement point of the change between the third (mid stance) and fourth (terminal stance) phases in the knee), but it seems that they had perceptive problem when both segments moved, and a much smaller problem when one segment was dominantly stable, and only one moved (e.g., there were more than 90% (N = 172) correct answers in the third measurement point of the change between the sixth (initial swing) and seventh (mid swing) phases in the hip, where an open kinetic chain movement included relatively stable pelvis that supports anterior motion of the femur).

The results of the first point of measurement (less than 50% of correct answers (43.96%)) could have been influenced by two factors: inaccuracy in the selection of photos (which were extracted from the video) that adequately represent a particular phase of the gait cycle, and the possibility that the subjects did not walk normally (i.e., they were speeding up or slowing down, their vertical centre of body mass displacement was too great, etc.).

For that reason, at the second measurement point, one subject was selected, and eight positions (i.e., photographs) were selected by an experienced practitioner, so that all participants observed identical material.

However, in the third measurement point, regardless of the additional PowerPoint support in the observation, there was no improvement; the participants seem to have reached their maximum. To further improve the precision, optoelectronic biomechanical analysis is needed, especially for the ankle. Most of the problems with direct measuring techniques (e.g., goniometry) can be overcome with optical measuring methods (Mihradi et al., 2013). However, as Eichelberger et al. (2016) emphasize, careful optical motion capture system configuration combined with thorough control of the measurement process is required to produce high quality results. Furthermore, passive marker tracking (even with optokinematic such as Kinovea motion analysis software or with an automatized optokinematic analysis system (e.g., BTS, Vicon)) is more precise than selecting prominent anatomical points on a 2D photo or video. In their systematic review from 2020, Michelini et al., referring to the findings of Ross et al. (2015), point out that by using markers we can expect higher intra-rater and inter-rater intraclass correlation coefficient values. For two-dimensional motion analysis, Fatone and Stine (2015) also suggest using markers, since manual digitization where markers are not present is time-consuming and potentially error prone.

In a reliability study by Ross et al. (2015), the testers were an experienced physiotherapist and two final year doctoral students in physiotherapy. Intra-rater reliability using the same video frame without markers or practice for students was relatively poor to moderate, while for an experienced physiotherapist it was moderate to high.

It is certain that the lack of observation and digitization practice is even more problematic for first-year bachelor level physiotherapy students.

Please note that the educational goal of these seminar tasks was not to check knowledge through the accuracy of answers (after all, the participants were students of the first semester of the first year of bachelor study), but rather to encourage them to think and make them aware of the importance of quality observation for future specialists in the field of physiotherapy.

4.1 Limitations

The study included only novice students. It would be interesting to make a comparison with the results of final-year students, and especially experienced professionals.

Furthermore, when using the symbols F (for flexion), E (for extension) or X (in case there is no change in angle between phases), the "gold standard" (e.g., Perry et al., 1996) seems to have reached its clinical endpoint due to the mathematical inconsistency of X symbol registration. It is obvious that students' error may have heterogeneity included within higher "sampling" rate (in Hz) – i.e., even the slightest F/E occurrence were registered (X means a fixed value without "acceptable range", and biology rarely manifests likewise) – and it is specially in concordance with e.g., high-tech industry expectations. Revealing this limitation also serves future establishment of "new gold standard" with 2D/3D automated video analyses included as a support to outreach of observational subjectivity limitations.

5 CONCLUSIONS

In Gericault's painting of a galloping horse, the outstretched front and rear limbs successfully depict fast movement. However, that expansions are too extreme to be realistic, which is consistent with the expansion of Gericault's artistic expression from neoclassicism to romanticism. However, in biomedical science, biomechanics and clinical practice, there is no room for romanticism, but an exact and precise approach to assessment is required. From that perspective, in the context of ideals, Muybridge is the ultimate winner over Gericault. In a practical sense, on the example of gait analysis, the same may apply to optokinematics in relation to observational methods.

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