Retrieval of Similar Behaviors of Human Postural Control from the Center of Pressure in Elderly People with Sarcopenia

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Abstract: Human postural control acquired by a force plate is an object of study in different Healthcare areas. However, researchers without much experience in other areas of knowledge, such as Statistics and Information Technology, observe their data only quantitatively. Therefore, as complement to these biomechanical analyses, this paper aims to compare, retrieve and visualize similar behaviors of the Centre of Pressure (COP) measured according to static positions performed by elderly people with sarcopenia, before and after the application of a muscular training intervention. For this purpose, the medial-lateral (ML) and anterior-posterior (AP) directions of the COP's oscillations are used, respectively, as coordinates on the x- and y-axes, to which the Fourier Transform is applied to extract features from each set of coordinates that will represent each data collection during comparisons by the Euclidean distance metric. The acquisitions are ranked based on the similarity they share with the one defined as query. As a result, only acquisitions of interest are retrieved. Case studies involved comparisons of pre- and post-intervention data collections from 4 subjects performing different static positions on the force plate. Scatter plot visualizations, combined with comparisons and retrievals of similar behaviors among COP's oscillations, facilitate analyses and insights regarding the subjects' postural balance performance during force plate data collections.

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1 INTRODUCTION

Force plates, as biomechanical equipment, are responsible for measuring data and information that reflect the human body's movement in the context of different work and daily activities (Uê *et al.*, 2024). In particular, observations and evaluations of human postural control during the performances of these tasks are essential for providing knowledge related to many Healthcare areas, including Physiotherapy, Biomechanics and Ergonomics (Advanced Mechanical Technology, Inc., 2020).

However, analyses of data acquired by force plates are more commonly based on a quantitative approach involving mathematical software (e.g., MATLAB and SPSS), which require researchers to have prior knowledge to be able to operate them (Dunn *et al.*, 2017). Consequently, researchers in the Healthcare areas with less experience in other areas of knowledge (e.g., Statistics and Information Technology) become dependent on the support of others to operate the software or on a prior and basic training (Uê *et al.*, 2023). Hence, despite the predominance of statistical results for biomechanical research (e.g., assessment of static postural control), qualitative information has its importance in biomechanical analyses as it provides another way of looking at a set of data (Uê *et al.*, 2024). A visual data analysis provides an overview of all the data collected or the values calculated from them for the variables of interest, displaying how they all relate, in contrast to quantitative information that summarizes an entire human body's performance in a single numerical value, as is the case with calculating a statistical average (Uê *et al.*, 2024).

For the purpose of applying a different approach to visually analyzing force plates data, Information Retrieval techniques embraces the processes of storing, organizing and representing information so that only those of interest to the user can be easily retrieved, providing information from documents, web pages, multimedia objects and other forms of

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content, both structured and non-structured (Baeza-Yates and Ribeiro-Neto, 2013). Therefore, in principle, the resolution of problems in this area aims to retrieve all relevant content to a user's query, while trying to include the minimum amount of irrelevant content. Nowadays, the scope of Information Retrieval applications ranges from text indexing, modeling and classification to user interfaces and data visualization (Baeza-Yates and Ribeiro-Neto, 2013). Additionally, it consists in an area with strong interdisciplinary potential, extending its applications across various domains of knowledge, including Healthcare.

Retrieving information that is similar to the one adopted as reference, or query, is commonly applied in the context of data acquired over a period of time, i.e., time series. In order to measure and rank the similarity between sets of values of this category, features can be extracted from them so that these attributes represent each set during their comparisons. Consequently, distance metrics are applied to rank the level of similarity, based on the characteristics obtained for each data vector.

As a method for extracting features, also referred to as descriptors, a set of values represented in the time domain is converted to the frequency domain. For this purpose, the Fourier Transform provides a means of applying these transformations, resulting in the acquisition of the power spectral density of the data (Quijoux *et al.*, 2021). Once Fourier descriptors are extracted, they compose a feature vector able to quantitatively describe each set of values that was initially modeled as a time series. The task of feature extraction for later analyses and comparisons is best performed in the frequency domain, since it allows for greater distinctions between descriptors representing each data vector (Villegas *et al.*, 2024).

The aim of this paper is to compare, retrieve and visualize similar performances of oscillations from the Center of Pressure (COP) in elderly people with sarcopenia during data collections on a force plate, before and after muscular training intervention. Therefore, the process of recognizing similar postural balances, involving data collections from a single subject or several ones and whether they improve or worsen their balance after the application of the intervention, becomes much easier and faster.

For visualization of the COP's performance throughout the duration of a data collection on the force plate, it is possible to combine one of its displacement directions by the other, i.e., to graphically display each value measured at an instant of the acquisition in the medial-lateral (ML) direction by its respective anterior-posterior (AP) direction that occurred at the same instant of time (ML x AP) (Uê *et al.*, 2023). Hence, the oscillations of the Center of Pressure were represented visually through scatter plots. This visual representation facilitates the perception of how the data is concentrated or scattered, indicating a good or poor postural balance, respectively. Furthermore, scatter plots can have their values colored according to the instant of time at which they were measured during data collection.

For comparisons between data collections, the COP's oscillations in their ML and AP directions were used to be extracted features from them, after converting each set of coordinates from the time domain to the frequency domain. This conversion was applied using the Fourier Transform. The transformed x and y coordinates were then merged into a single feature vector, or Fourier descriptors vector, representing the acquisitions. As a result, it is possible to compare the feature vectors that describe each data collection to be able to identify similar Center of Pressure's behaviors and, therefore, retrieve only those acquisitions that have similar postural balances.

This paper is organized as follows: Section 2 presents research that analyze biomechanical data acquired from force plates by using both time and frequency domains, along with data visualization and classification techniques; Section 3 describes the methodology employed to achieve the aim of this paper, including the collection of force plate data and its steps of processing, treatment, transformation, comparison, visualization and analysis; Section 4 provides the results obtained after applying the developed methodology to different case studies, regarding the postural control in elderly people with sarcopenia at pre- and post-muscular intervention moments, with discussions on the visual analysis of the results. The last section, Section 5, presents the conclusions, advantages and benefits provided by the development and application of this paper's methodology.

2 RELATED WORKS

Jeong and Ohno (2017) conducted an evaluation of the differences that work experience provides in the workers' Center of Pressure during symmetrical load lifting with eyes closed. The first group of participants was composed of 20 trained and experienced subjects from a transportation company, and the second one was composed of six university students with no training or skills for this context. The Wii Balance Board force plate was used to measure the COP's displacements, from which the velocities of them in both time and frequency domains were calculated. The Fourier Transform was used to convert the velocities' time series to the frequency domain. For recognition of patterns and differences between the postural balance of experienced and non-experienced subjects, the Linear Discriminant Analysis (LDA) classifier was applied to the features extracted by Fourier Transform. For implementation of visual representations, graphs of the medial-lateral direction of the COP's displacement by its anterior-posterior direction were used, along with graphs for both time and frequency series of the velocities reached by the COP throughout the data collections.

Rahmati *et al.* (2019), based on the participation of 40 Parkinson's patients in a balance training over 12 sessions, aimed to evaluate the effectiveness of their training program. Authors also investigated the neurophysiological aspects of the balance performance in Parkinson's patients and how training can assist in the rehabilitation of their postural control. Data related to the Center of Pressure was measured using a force plate, where subjects performed two attempts under the conditions of eyes open or closed, while standing on a rigid or foam surface. 20 healthy subjects participated in the experiment as a control group. To compare the results between groups, time series for the trajectories and velocities of the COP's displacement were visualized and analyzed, along with the Power Spectrum Density (PSD) of these same parameters by using the Fourier Transform, resulting in a comparative view in frequency domain.

Park *et al.* (2024) assessed the postural control of 72 subjects diagnosed with idiopathic normal pressure hydrocephalus (iNPH) and 56 subjects who tested positive in the cerebrospinal fluid tap test (CSFTT). Patients were evaluated in a static posture with their eyes open, on the day before and after the test. A force plate was used to acquire data related to the Center of Pressure's performance, whose parameters were calculated in the time and frequency domains for subsequent comparison between pre- and post-CSFTT results. Python programming language and its signal processing package, SciPy, were used for the analysis. COP's trajectories in the frequency domain were analyzed using the Fourier Transform and Power Spectral Density. For visual analyses, graphs were implemented for one of the COP's displacement directions by the other, in addition to the medial-lateral and anterior-posterior directions being displayed individually by both time and frequency.

Villegas *et al.* (2024) employed the Wii Balance Board force plate to measure data related to the Center of Pressure, with the aim of identifying patterns and distinctions between static postural behaviors of 32 elderly people classified into three groups: diabetics; healthy people; and those presenting diabetes with diagnosed diabetic neuropathy. Over 30 seconds, the subjects performed: standing posture under the conditions of eyes open and closed; on stable and unstable surfaces; and performing, or not, a second cognitive task. Values measured for COP's oscillations in the ML and AP directions were represented by time series, from which features were extracted to be compared and classified using machine learning methods. The feature extraction was also applied to COP's parameters converted into the frequency domain, since the spectral power is better suited to distinguish different groups compared to temporal characteristics. To this end, the Discrete Fourier Transform was applied to the temporal data to transform them into a feature vector in the spectral power domain. Among the selected machine learning classifiers were the K-Nearest Neighbor (K-NN) method, which enables pattern recognition by comparing the Euclidean distance between a data used as a reference/query and the remaining data in the sample.

3 MATERIALS AND METHODS

Data collections used in this paper were conducted by Bertolini *et al.* (2021), using OR6-6 force plate model from Advanced Mechanical Technology, Inc. (AMTI). The aim of their study was to evaluate the static postural control of elderly people with sarcopenia, who's balance is affected by the loss of muscle mass, before and after a 12-week muscular training intervention (Bertolini *et al.*, 2021). Each subject was positioned on the surface of the force plate and made three attempts at the static positions of feet together (FT) and feet apart (FA) with eyes open (EO) and eyes closed (EC) for 30 seconds; as well as the semi-tandem positions (ST) with eyes open and closed; and unipodal stance with the dominant foot and non-dominant foot, for ten seconds (Bertolini *et al.*, 2021). Data was collected at a frequency of 100 Hz.

The force plate measures the ground reaction force components and their respective torque moments acting on the x-, y- and z-axes of an orthogonal coordinate system (Advanced Mechanical Technology, Inc., 2020). The components of force and their moments are measured according to the action performed by the subjects on the surface of the plate. Actions can be characterized as static (e.g., subject standing still with changes in relation to the positioning of their feet or to the condition of their vision or surface) and dynamic (e.g., subject performing a jump, walk or run). By obtaining the force and moment values during data collections, it is possible to calculate the behavior of the subject's Center of Pressure over time in its medial-lateral and anterior-posterior displacement directions, corresponding to right-left (on the x-axis) and front-back (on the y-axis) displacements, respectively (Duarte and Freitas, 2010). The COP is a measure of positioning that has the force plate as the biomechanical equipment commonly used to measure it, and the observation of the COP's behavior is used as the most significant evaluation of human static postural control (Duarte and Freitas, 2010).

For each static position performed by the subjects and collected before and after intervention, the values acquired for the Center of Pressure's oscillations in its medial-lateral and anterior-posterior directions were used to represent, respectively, coordinates on the x- and y-axes belonging to each point of the COP's displacement throughout data collection. Hence, every static position performed by a subject on the surface of a force plate has oscillations in the ML and AP directions of the Center of Pressure. By representing these displacement directions as coordinates for the x- and y-axes, the Fourier Transform was applied to these two sets of values to extract descriptors from them, characterizing and describing the COP's behavior throughout each data collection. Therefore, it becomes possible to distinguish or assimilate an acquisition to others that have different or similar displacements in the x- and y-axes. With the combination of the two sets of Fourier descriptors, a feature vector was obtained to represent the COP's behavior and to be used to make similarity comparisons with feature vectors extracted from other data collections.

As a method to compare the oscillations of the COP obtained during the pre- and post-intervention data collections, data was transformed into features to describe and represent a data collection. This process enables the calculation of a similarity distance between acquisitions. For this purpose, the Fourier Transform was applied to both sets of coordinates (one with values on the x-axis and another with values on the y-axis) and, from the resulting values, the data extracted from each set were those that belonged to the interval starting from the central value subtracted by ten, and ending at that same central point added to ten. By including the middle value, a total of 21 data points were extracted from each set, which are referred to as Fourier descriptors. By merging these descriptors obtained with the Fourier Transform applied to both sets of coordinates, a new set was generated, named feature vector, containing 42 descriptors. The first half of values in this vector correspond to the feature extraction from the coordinates on the x-axis while the second half corresponds to the same process for the y-axis.

To determine how similar the Center of Pressure's performance is from one data collection to another, the Euclidean distance metric was applied to compare the feature vectors acquired from each static position. Based on this metric, it is defined that the shorter the distance results, the greater the similarity. And the longer the distances, the less similar the data collections will be to one another.

The COP in its medial-lateral and anterior-posterior directions of displacement was visualized in the form of scatter plots colored to be distinguished by subject, positioning and moment of intervention. The displacement values in the graphs were also individually colored to reflect the instant of time they occurred during data collection. All steps of data processing, treatment, analysis and visualization were accomplished by using Python programming language.

Finally, in addition to comparisons based on Euclidean distance, the feature vectors acquired from different data collections were submitted to the PEx-Image (Projection Explorer for Images) software, developed by Eler *et al.* (2009), to visualize how they are positioned within a feature space, where similar vectors are represented by points close to each other and, as the points are getting further apart, there is a perception of how distinct the feature vectors are. With this application, it was also possible to connect sets of points that were close and similar with the K-Nearest Neighbor machine learning classifier method. This algorithm provides connections between the most similar neighboring acquisitions and separates them from their more distant neighbors.

4 RESULTS ANALYSIS

As a case study to demonstrate the developed application, the data collections acquired from a force plate for four different elderly people with sarcopenia were evaluated during the pre- and post-intervention moments of a muscular training program. Each subject performed three attempts at the static positions of FTEO, FTEC, FAEO, FAEC, STEO and

STEC at both intervention moments. In total, 144 data collections were gathered, from which the displacements of the Center of Pressure in its medial-lateral and anterior-posterior directions were calculated, representing the balance and postural control behavior of the subjects during the performance of each position. For a visual representation of the postural behavior, scatter plots were modeled to display the coordinates obtained for each COP oscillation along the x-axis (medial-lateral direction) and y-axis (anterior-posterior direction).

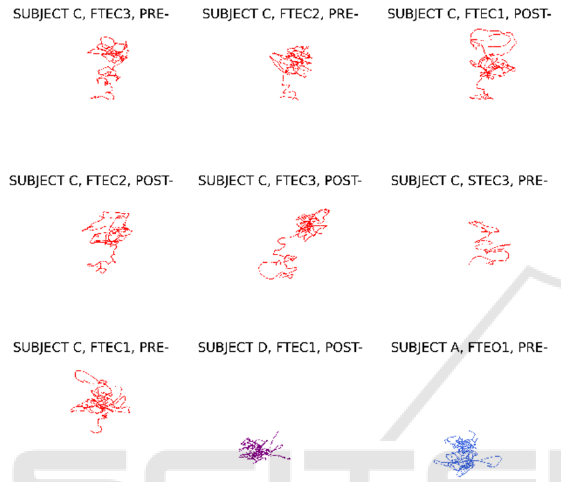

Figure 1: ML x AP scatter plots colored by subjects and ranked in ascending order of Euclidean distances measured in relation to the COP's performance during the positioning defined as query (FTEC3 in the pre-intervention) and compared to other acquisitions.

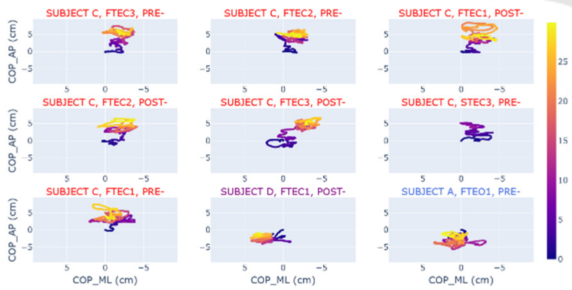

Figure 2: ML x AP scatter plots colored by time; with titles colored by subjects; and ranked in ascending order of Euclidean distances measured in relation to the COP's performance during the positioning defined as query (FTEC3 in the pre-intervention) and compared to other acquisitions.

For each acquisition, the Fourier Transform was applied to the coordinates of both x- and y-axes; the Fourier descriptors were extracted from each set of resulting values; the two sets were unified, defining a feature vector to now represent the data collection; and a visual analysis was then performed for two cases of retrieving similar acquisitions from one defined as the query.

In one of the cases, the aim was to retrieve data collections containing CP displacements indicating large oscillations, i.e., imbalances throughout time. For this purpose, the third attempt to perform the feet together with eyes closed (FTEC3) position from the elderly person identified as the letter C, which was acquired before the intervention applied to the subjects, was used as the query. This means that its feature vector, that represents it, was compared with those features representing the other acquisitions by using the Euclidean distance metric. Figure 1 illustrates the ranking in ascending order of the distances obtained in relation to the subject's COP behavior during the data collection used as a query, corresponding to the first graph in the top left corner. The remaining scatter plots represent the 8 acquisitions most similar to the query, arranged from left to right and top to bottom in order of similarity. Therefore, as there are larger similarity distances with the query, these data collections will be positioned less close to it. It is also important to emphasize the relevance of the retrieval process, since it provides a means for gathering acquisitions from the same subject, even at different moments of intervention and with different positions.

For the visualizations, as it is changed which aspect that is being highlighted in the graphs of each figure, it is important to emphasize that different ways of coloring the graphs indicate that it is possible to evidence different parts of the data collection, facilitating the perception and analysis of the data. In the first coloring method, visualizations were colored red, green, blue and purple, so that each subject is represented by one of these colors. The data collections belonging to the elderly person, whose one of his acquisitions was used as query, were colored red. Figure 1 shows that the first 6 collections most similar to the query belong to the same elderly person (colored red). The last two acquisitions belong to other two different subjects. As a result, more than half of these unbalanced retrieved acquisitions belong to the same subject.

Figure 3 shows the representations of static positions being colored by the type of positioning performed (second form of coloring). It can also be noticed that the differentiation between eyes open and closed for the same position is due to the change in the tonality of the same color (e.g., light blue for the feet together with eyes closed (FTEC) position and dark blue for the feet together with eyes open (FTEO)

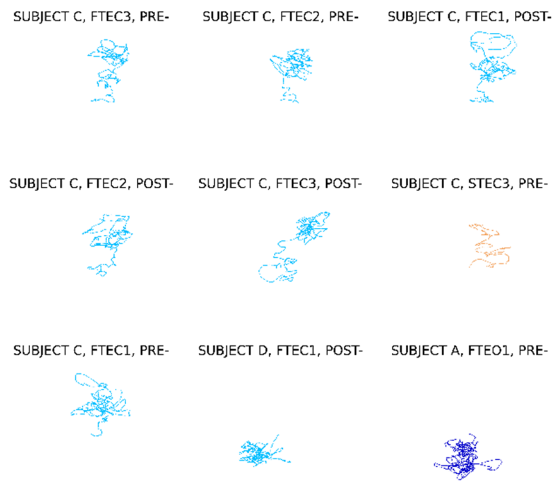

Figure 3: ML x AP scatter plots colored by positions and ranked in ascending order of Euclidean distances measured in relation to the COP's performance during the positioning defined as query (FTEC3 in the pre-intervention) and compared to other acquisitions.

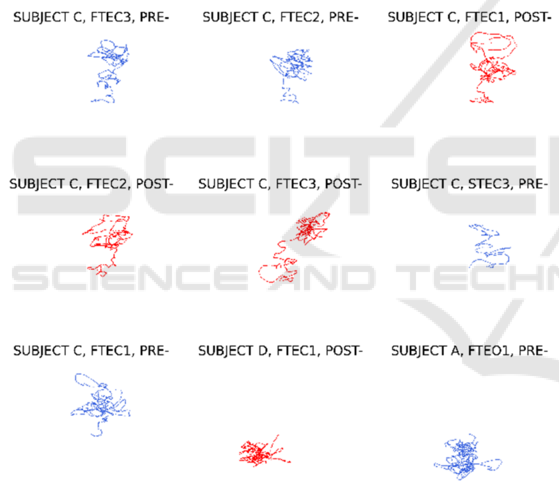

Figure 4: ML x AP scatter plots colored by moments of intervention and ranked in ascending order of Euclidean distances measured in relation to the COP's performance during the positioning defined as query (FTEC3 in the pre-intervention) and compared to other acquisitions.

position). Thus, nearly all retrieved acquisitions involved feet together performances and, within this group, there is a predominance of data collection with eyes closed.

A third method of coloring the scatter plots corresponds to the differentiation between pre- and post-intervention acquisitions (Figure 4). Positions collected before the intervention are colored blue and those collected after intervention are in red. This modeling illustrates a greater presence of pre-intervention positions in the recovered data collections. Furthermore, it is important to notice that the retrieval process identified many of the most similar acquisitions to the query as being from the same subject (Subject C), collected both pre- and post-intervention. This consistency in retrieving the same subject among those with most similar data collections to the query, at any moment of intervention, reflects the fact that the algorithm succeeds in retrieving similarities. Another consistency that can be observed is that, even in different acquisitions and moments of muscular training, subject C maintains the same behavior.

In addition, scatter plots were also modeled in which each COP displacement value was colored according to the time, in seconds, that it occurred during data collection. The visualizations were colored so that the darker colors (e.g., blue) corresponded to the beginning of data collection, while the lighter colors (e.g., yellow) indicated the final instants. With this method of visualization, it is possible to observe the temporal behavior of the COP and at which instants (beginning, middle or end) the displacement oscillations occur or not. Because the graphs were already colored on a time scale, the text titles of each acquisition were colored to distinct the different subjects who performed it, as illustrated in Figure 2. The texts were also colored according to the moment of intervention and to the type of positioning performed. By adding the time variable, the COP oscillations can be better understood. In this case of retrieving unbalanced data collections, the greatest variations occur when the colors are darker (start of the collection) and as the end of the period approaches (lighter colors), some acquisitions manage to reduce the amplitude of the COP displacements, i.e., the subjects found a point of balance despite an oscillating start.

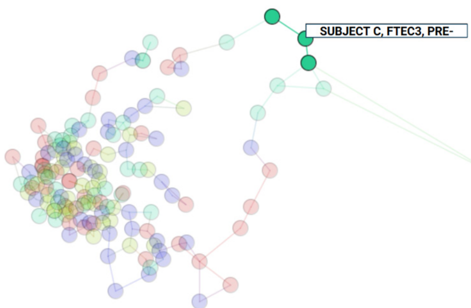

Figure 5: Feature space, where feature vectors, representing each acquisition, correspond to points colored by subjects and connected based on the KNN classifier, highlighting the query (FTEC3 in the pre-intervention) and its most similar neighbors.

After visualizing different styles of scatter plots, the feature vectors for each data collection were submitted to PEx-Image software, in which the feature space with all acquisitions was visualized. The application provides the multidimensional projection technique Interactive Document Map (IDMAP) to be used for the visualization of the Fourier descriptors vectors within the feature space (Minghim *et al.*, 2006). The points representing similar vectors in this space were connected after applying the K-Nearest Neighbor classification algorithm. This connection between data points, highlighting the one representing the query and its nearest neighbors, is illustrated in Figure 5, where acquisitions are colored by subjects. Therefore, the query data collection belonging to subject C is colored green, and it has other acquisitions from the same subject as its most similar. Additionally, there are more green-colored points which are also closer to the query. The largest cluster of points on the left side of Figure 5 indicates acquisitions sharing a greater number of similar characteristics, resulting in a large concentration of points. This form of visualization by displaying the feature space, contributes to the information retrieval process, as it provides an overview of the similarities between all acquisitions performed by all subjects.

On the other case study, acquisitions with a higher concentration of COP displacement values were retrieved, indicating a more desirable balance. Figure 6 illustrates the scatter plot visualizations modeled to represent the behavior of the Center of Pressure measured during the executions of each static

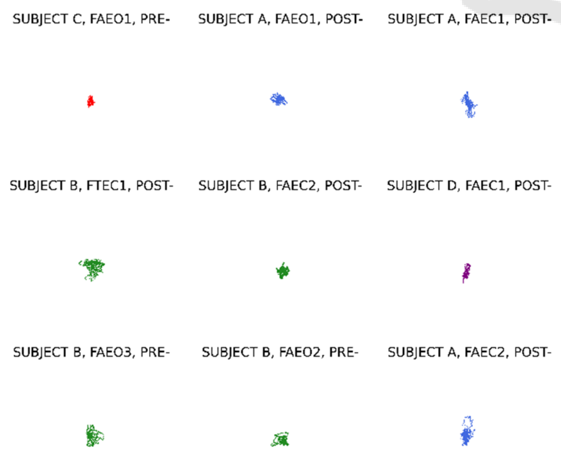

Figure 6: ML x AP scatter plots colored by subjects and ranked in ascending order of Euclidean distances measured in relation to the COP's performance during the positioning defined as query (FAEO1 in the post-intervention) and compared to other acquisitions.

position. The positioning defined as query for the comparisons with other acquisitions corresponded to the first attempt at the feet apart with eyes open (FAEO1) position performed during pre-intervention.

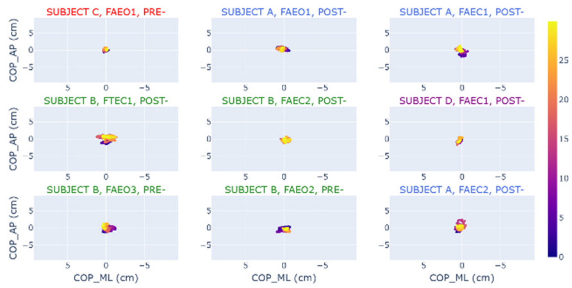

Figure 7: ML x AP scatter plots colored by time; with titles colored by subjects; and ranked in ascending order of Euclidean distances measured in relation to the COP's performance during the positioning defined as query (FAEO1 in the post-intervention) and compared to other acquisitions.

The visualizations for this case were also colored in different ways for each figure, highlighting different parts of the data collection to provide more insights and an easier analysis of the data. By coloring the visualizations to differentiate the subjects, as seen in Figure 6, it is possible to notice a greater presence of elderly people whose data collections are in green and blue.

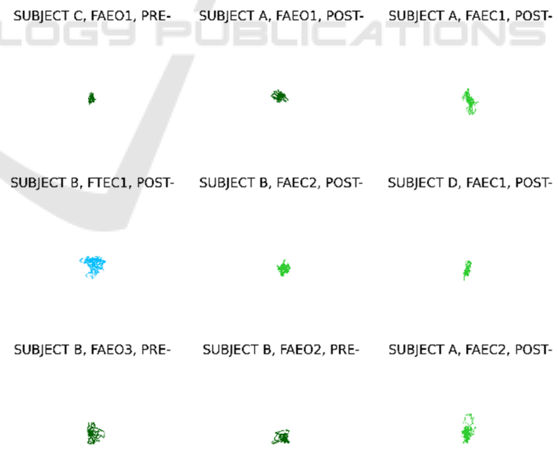

Figure 8: ML x AP scatter plots colored by positions and ranked in ascending order of Euclidean distances measured in relation to the COP's performance during the positioning defined as query (FAEO1 in the post-intervention) and compared to other acquisitions.

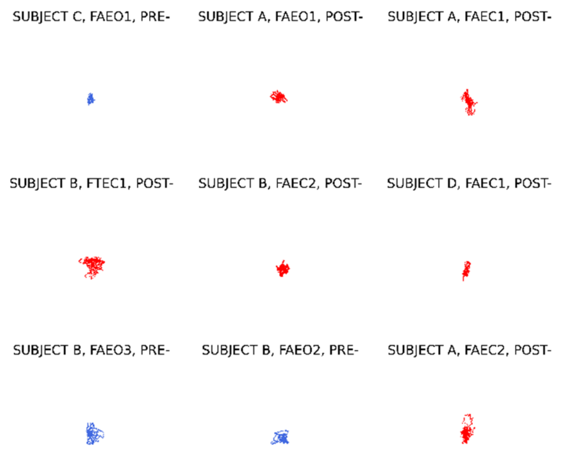

Figure 9: ML x AP scatter plots colored by moments of intervention and ranked in ascending order of Euclidean distances measured in relation to the COP's performance during the positioning defined as query (FAEO1 in the post-intervention) and compared to other acquisitions.

On the other side, by coloring the graphs according to the type of positioning, as seen in Figure 8, it is possible to observe the majority presence of green coloring, whether in light or dark tones, indicating the attempts to perform the feet apart position with eyes open (FTEO) or closed (FTEC).

By coloring the scatter plots according to the intervention moment at which each type and attempt of positioning was performed (Figure 9), it is possible to observe a dominant presence of post-intervention data collections colored in red among the first ones retrieved, just as in the overall picture compared to the amount of data collections in blue (pre-intervention). It is also possible to notice from the retrieval results that some subjects (Subjects A and B) maintained a consistency in their balance behavior from pre- to post-intervention, in relation to some of the positions, especially the FAEO one. Those elderly people were able to achieve a more concentrated postural balance, both before and after muscular training.

The addition of the time variable to the modeling of the scatter plots is illustrated by Figure 7 (with text titles colored by subjects). The titles were also colored by both positions and moments of intervention. With this form of visualization for this case study, it is possible to notice a greater balance of the subjects due to a concentration of their COP displacement values, occupying less area in the graphs. Furthermore, the overlapping of the colors, that indicate the time at which each displacement value occurred in the collection, also indicates less variations in the data, as the light colors (end of data collection) mostly overlap the dark colors (beginning of data collection).

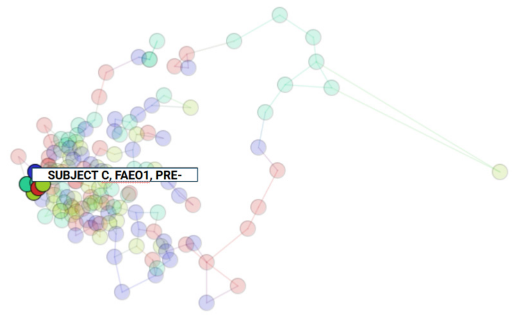

Figure 10: Feature space, where feature vectors, representing each acquisition, correspond to points colored by subjects and connected based on the KNN classifier, highlighting the query (FAEO1 in the post-intervention) and its most similar neighbors.

After applying the feature vectors, that were defined for each acquisition, to PEx-Image software, the visualization of the feature space was modeled with the projection technique of IDMAP, as each vector is being represented as a data point connected to those most similar to it, through the K-Nearest Neighbor method. Figure 10, where acquisitions are colored by subjects, illustrates the KNN algorithm's results, in which only the point representing the query vector and its most similar neighbors was selected and highlighted. In this case, there are points with different colors besides the green representing the query. Therefore, there are other subjects' data collections very similar to subject C's acquisition defined as query. It is also possible to observe that the nearest neighbors to the query are in the largest cluster of points on the left side of the image, indicating multiple data collections from multiple subjects that are also highly similar.

5 CONCLUSIONS AND DISCUSSIONS

The force plate biomechanical equipment measures data that provides information about the human body movement, i.e., its behavior and postural control (Uê *et al.*, 2024). However, analyses of this data require researchers to have experiences and a greater understanding of other areas of knowledge in addition to the Healthcare ones (Dunn *et al.*, 2017). In consequence, statistical analyses involving force plate data are often conducted without a qualitative view of the results to complement it (Uê *et al.*, 2023).

A visual analysis provides an overview of the data and how they are related to each other, without summarizing the human body's behavior in a single statistical value (Uê *et al.*, 2024).

With data collected using a force plate, it is possible to use visualizations (e.g., scatter plots) to qualitatively observe the performance of a subject's Centre of Pressure in its medial-lateral and anterior-posterior directions during a data collection (Uê *et al.*, 2023). From these displacement directions acquired for each acquisition, it is possible to use feature extraction techniques, also referred to as descriptors, so these can be compared with other features extracted from COP's displacements belonging to other acquisitions (Baeza-Yates and Ribeiro-Neto, 2013). Once distance metrics are applied to compare data collections, these can be ranked according to their level of similarity, allowing the user to retrieve only acquisitions that are similar to the one defined as their interest, which is used as query (Baeza-Yates and Ribeiro-Neto, 2013).

The aim of this article is to compare, retrieve and visualize, in a ranked manner, similar performances of the COP's displacements in elderly people with sarcopenia, during data collection on the force plate before and after a muscular training intervention. Consequently, the recognition of similar postural balances is optimized and automatized for the comparisons of acquisitions belonging to the same or different subjects.

For comparisons between data collections, values obtained by the oscillations of the Center of Pressure in its ML and AP directions were used to correspond to coordinates on the x- and y-axes, respectively. Fourier Transform was then applied to each of these two sets of values to extract descriptors from them, which combined characterized and described the behavior of the COP during an acquisition. Having defined the sets of Fourier descriptors values (or feature vectors) to represent each data collection, these vectors were compared with an acquisition defined as query. Then, the feature vectors of all acquisitions were ranked using the Euclidean distance metric, so similar behaviors would have smaller distances from the query, placing them close to it. In the opposite way, the greater the distance result, the less proximity the data collection shares with the query.

For the case studies, performances of four different subjects were compared by using their three attempts for the static positions of FTEO, FTEC, FAEO, FAEC, STEO and STEC, in pre- and post-intervention moments (Bertolini *et al.*, 2021). In the first case, comparisons were made between data collections that presented large oscillations during the displacement of the COP, i.e., the values were scattered across the area of the graph. One of these acquisitions that involved many postural imbalances was defined as the query, so that behaviors most close to it were ranked and retrieved. Results from the retrieval of data collections similar to the one defined as query were visualized through scatter plots, where values were colored to differentiate the subjects, positions, and moments of intervention. Similarly, in another visualization model, these three coloring forms were used in the titles of each acquisition, because the COP's oscillation values were colored according to the instant of time in which they occurred.

In the second case, the query was defined as an acquisition whose COP's displacement values were more concentrated and placed at the center of the scatter plot, indicating a focused and desirable balance. The same forms of coloring by subjects, positions, moments of intervention, and time, were also used for the visual analysis of the results for the most well-balanced data collections retrieved based on the one defined as query.

Based on the developed approach of analysis, it was possible to identify that subjects A and B presented the largest number of data collections with a concentrated postural control and few variations in its amplitude. Similarly, most of performances from feet together with eyes open (FTEO) and eyes closed (FTEC) positions were retrieved when it was desired to observe COP's behaviors whose displacement values were more concentrated. There was also a more significant presence of post-intervention acquisitions among the first data collections ranked. In contrast, subject C presented the greatest balance difficulties, especially when performing the FTEC position at both pre- and post-intervention, as his displacement values were more dispersed across the area of the graphs. In general, the execution of feet together position resulted in the greatest variations in postural control. Additionally, most of these retrieved data collections exhibiting the subject's difficulties in finding their balance point, were taken in the moment prior to the intervention.

Therefore, as methods to compare performances of the Center of Pressure acquired in each data collection, the feature extraction and the ranking of acquisitions according to the one defined as a base, i.e., a query, consist of techniques that make it possible to retrieve data collections presenting similar performances of the subjects' postural control. Thus, by associating each acquisition with a visual representation, it becomes faster and easier to qualitatively analyze which positions, and in which attempts the subjects performed in a more balanced way and with fewer COP's oscillations, or also, which positions and attempts showed the most postural imbalances. In addition, coloring the data values facilitates comparisons between subjects; positions; moments before and after intervention; and time of collection, whether for the same subject or for comparisons of different sets of individuals who performed actions in contact with the surface of the force plate.

For future work, the inclusion of professionals and researchers, who are familiar with force plates, is essential and of extreme importance in evaluating the proposed visual analysis method's usability. Users' participation, based on interviews and their perceptions on the visual results, is a fundamental assessment metric which provides their observations, opinions, and narratives regarding the advantages and potential improvements of the developed approach to analyze postural balances acquired from force plates.

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