

Analyzing working conditions for classical guitarists: design guidelines for new supports and guitar positioning

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Abstract.

BACKGROUND: When performing, classical guitarists interact with many elements which constitute their own “workstation”. One of those elements is the support for guitar positioning. Support dimensions, form and materials may determine posture and affect the musician’s comfort and performance.

OBJECTIVE: To propose design requirements for new supports for guitar positioning, based on postural assessment, anthropometric criteria, self-efficacy and comfort perception.

METHODS: Nine healthy Classical Guitar students were recruited. A postural assessment was undertaken using REBA, and 3DSSPP software with three different supports for guitar positioning. After the use of each support, a questionnaire about self-efficacy and comfort perception was completed by the participants.

RESULTS: The higher scores of risk and a significant difference (ANOVA, $p = \leq 0.05$) regarding the left leg elevation were found with footstool usage. However, this one was identified by participants as the best support in terms of self-efficacy and comfort assessment.

CONCLUSIONS: There is a need for designing support for guitar positionings to improve performance for guitarists and prevent physical injuries. This paper proposes eleven guidelines for designing these supports.

Keywords: Postural assessment, classical guitarists, ergonomic risks, support for guitar positioning, design guidelines

1. Introduction

The classical guitar is a popular musical instrument worldwide. When musicians perform it professionally, it is necessary to develop many physical and cognitive skills. Musicians invest long periods of practice, static postures and repetitive movements, to

achieve diverse abilities. Nevertheless, this demanding practice implies the appearance of physical risk factors.

Some studies indicate the prevalence of musculoskeletal injuries among musicians, some of them with particular emphasis in the string and guitar players. Kenny and Ackermann (2015), for example, examined a self-reported frequency and severity of performance-related musculoskeletal pain disorder scale applied in 377 professional orchestral musicians. Most musicians (84%) had experienced

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performance-impairing pain; 50% reported current pain. Females reported more performance-impairing pain and more current pain than males [1].

Lee et al. (2013) points out that the prevalence of musculoskeletal disorders in instrumentalists is relatively high, ranging from 73.4% to 87.7%. A survey in Korea revealed that 79.6% of orchestral players had musculoskeletal disorders and that the most frequently affected body parts were the shoulders (59.6%) and back (48.1%) [2].

On the other hand, Sanchez-Padilla et al. (2013) applied a survey to 40 participants of an international guitar contest in Barcelona with the purpose to identify the prevalence of playing-related injuries among guitarists; 67.5% of the participants had presented an injury in the last five years. The most affected body regions were the cervical spine (27.5% of the injuries in the past year), elbow/arm and wrist (22.5% and 20%, respectively, in the last year), shoulder (17.5% of injuries in the previous year), thoracic and lumbar spine (12.5% of the injuries in the previous year and 22.5% in the previous five years). Finally, hip and knee (17.5% and 7.5% of the injuries in the past 5 years, respectively) [3].

In general, there are three diagnostic categories of performance-induced medical problems among musicians: musculoskeletal or muscle–tendon pain syndromes (often referred to as overuse injuries), nerve entrapments, and focal dystonia [4].

The information mentioned above, shows the prevalence of physical problems in the guitarist activities, considering among others, repetitive movements, time of practice and poor postures. Regarding this, the information focused on preventing injuries in musicians has been growing; through new ways of practice, new exercises for muscle strengthening, performing warm-ups and stretches before and after practice, performing micro-pauses, education, etc. [5–9].

Several authors have established the necessity to improve work conditions to reduce the possibility of getting an injury [8, 9]. Nevertheless, there is not a lot of information on how, specifically. The guitarist “workstations” contribute to producing the mentioned problems and how the supports used by the guitarist are involved.

Different guitar supports for guitar positioning have been included in guitar performing to enhance the interaction between musicians and their instruments. These devices constitute the musician’s workstation and have an essential role in the development of their artistic activity. Some of these guitar

supports are used for guitar positioning to facilitate access to higher frets and to have better control during performance.

It’s important to recognize that classical guitar performance has been accompanied by new proposals of healthy playing postures, which abandons the tradition of using certain guitar supports in favor of various other alternative tools for guitar positioning [10].

However, there are different and new models, all of them with a particular design and different use. Besides, many builders and companies suggest that their products have certain biomechanical and ergonomic advantages to allow the guitarist to keep a most neutral posture. However, there is a lack of research on this topic, and there are other issues such as anthropometric variables and specific physical interactions between the guitarist and the musical instrument which are not taken into consideration.

The use of these devices is understandable because, as Johnson (2009) argues, the study of music includes biomechanical and other health issues in learning an instrument [10]. Therefore, it is necessary to have reliable support to improve this artistic activity and prevent musculoskeletal problems. For example, it is well known that playing an instrument requires specific posture and asymmetric position that may affect the normal spinal curvatures and may lead to postural asymmetry [11]. These conditions could represent important risk factors in the long run, especially if musicians don’t have these complementary devices.

Hence, this work aims to propose a group of design requirements for instrument positioning through the analysis of the interaction between the guitarist and three different supports for guitar positioning, based on postural assessment, anthropometric aspects and self-efficacy and comfort perception of music students. It is believed that tools for guitar positioning with ergonomic characteristics will improve conditions of the guitarist activities and will help to prevent physical problems.

2. Method

2.1. Participants

Nine classical guitar players (8 men and 1 female), studying between the first and third year of the music technician career at the University of Guadalajara, aged between 18 and 21 years old ($M = 19.6$, $SD = 1$) participated. All participants were volunteers in this study. The experience of playing classical guitar was a



Fig. 1. Adjustable height bench.

necessary requirement to participate in this research, due to the fact that musicians tend to adopt specific vicious posture patterns, or they might have some musculoskeletal symptoms after years of performing. The students had a minimum of 3 months playing the instrument and less than four years ($M = 1$ year and 8 months, $SD = 1$ year).

2.2. Scenario

The assessments were applied inside the facilities of the Center of Art, Architecture and Design of the University of Guadalajara. A classroom was isolated from any external distractions. All of the windows were covered using black cardboard, and any artificial climate was necessary. The evaluations were made in three different days, from 10 : 00 hrs. till 15 : 00 hrs.

2.3. Materials

Due to the nature of classical guitar performance, the participants accomplished the evaluations in sitting posture; using an adjustable-height bench (see Fig. 1).

The guitar supports evaluated were chosen considering their differences regarding design and way of use. 1. Guitar cushion (Fig. 3). 2. Rigid lap support (Fig. 4). 3. Footstool (Fig. 5).

To program a specific tempo (80 bpm), to perform the musical instrument and standardize the number of rounds, a digital metronome was used. All the musicians were video recorded using three video cameras model Go Pro Hero 6, located on the posterior, lateral and superior views. One of the cameras was controlled remotely using a tablet and the Go Pro application.

All of the participants used the same guitar, a handmade classical instrument from a Mexican builder from Paracho, Michoacan. This guitar had the standard required measures for a professional musician.

A musical exercise was written considering the interaction with low, middle and high zones on the fretboard. An introductory video with all the instructions was used. The video was focused on the objectives to accomplish during the test, including an explanation about musical exercise, instructions on how to answer the questionnaire and finally, information about the authorization form to be part of the study.

2.4. Instruments for postural assessment

The postural analysis was divided into two phases. The first one using an observational instrument with the purpose to have an initial diagnosis of the possible most risky postures, the Rapid Entire Body Assessment (REBA), developed by Hignett and McAtamney (2000) [12]. For the second phase it was necessary to apply a more in-depth evaluation, this time using the software 3D Static Strength Prediction Program (3DSSPP), developed at the University of Michigan by the Center of Ergonomics.

2.4.1. Instruments for the first phase of the postural assessment

REBA is an observational method that classifies postural risk into five different levels from (negligible risk, low risk, medium risk, high risk and very high risk) using an ordinal scale of 11 points (Table 1). This ergonomic assessment tool uses a systematic process to evaluate whole body postural musculoskeletal disorders and risks associated with job tasks. This method ensures that any awkward or constrained postures of the neck, trunk or legs are included in the assessment. For each region, there is a posture scoring scale and additional adjustments, which need to be considered and accounted for in the score [27].

2.4.2. Instruments for the second phase of postural assessment

After the first diagnosis it was necessary to apply a more in-depth evaluation, this time using the software 3D Static Strength Prediction Program (3DSSPP). The purpose of this software is to analyze physical exertion, body posture to estimate back compression forces, to evaluate reach or posture requirements (anthropometry) and, in general, to analyze the physical demands of the participant, through the simulation



Fig. 2. Video recording in three different angles.

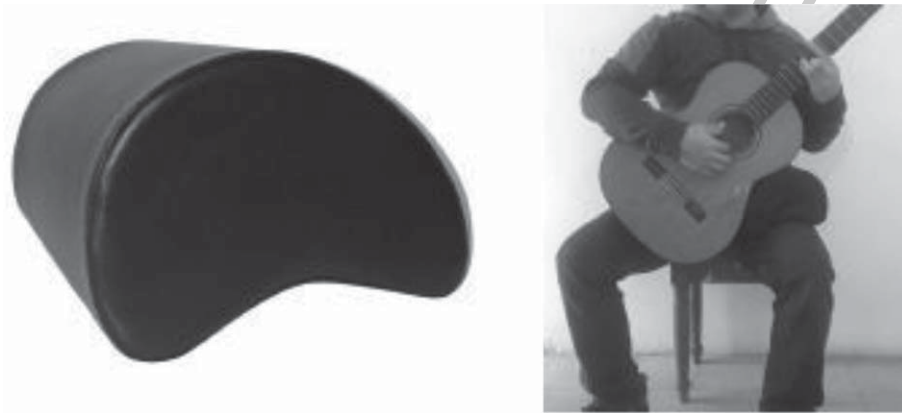


Fig. 3. Guitar cushion.



Fig. 4. Rigid lap support.

of the task in a three-dimensional environment. Hence, it was possible to enter certain information of the participant, such as weight, height, gender and external forces if necessary. To simulate the posture of musicians it was possible to manipulate a 3D model (avatar) that recreated joint movements and angles of the torso, shoulder, hip flexion and humeral rotation

and estimate low back compression at the level of L4/L5 joint. The measurement unit for joint postures were angles and newtons for low back compression.

To estimate the extent to which the supports for guitar positioning modify the sitting posture of musicians, a neutral sitting pattern programmed from the software was used as a reference. This pattern would



Fig. 5. Footstool.

establish the point where participants have a low-risk posture before using each auxiliary implement; therefore, all the modifications generated from the use of these devices would increase the postural risk as they move the musician away from the initial sitting posture reference. All the assessments made with this software reported a medium, high or very high risk classification with REBA.

2.4.3. Instruments to estimate comfort and self-efficacy perception

To evaluate self-efficacy and comfort perception, a questionnaire was developed. With the purpose of having more validity of the items, some criteria proposed by Sampieri (2014) were followed.

One of these criteria was the construction of validity and was focused on a literature review to define dimensions inside the concepts of self-efficacy perception and comfort. The defined dimensions for self-efficacy perception were: 1. Control over the instrument and 2. Perceived self-confidence in terms of keeping the guitar in a desirable position without moving and having an efficient performance.

For comfort, the defined dimensions were: 1. The possibility of maintaining a neutral and comfortable posture while playing; 2. Perceived aesthetic aspect of the guitar support and 3. User experience after using the guitar support. For each dimension, two statements at least, were developed, following what was stated by Sinclair (1995).

Subsequently, three experts in ergonomics, behavioral sciences and design, analyzed the content of the items and their order. Finally, the questionnaire was applied in a pilot test, with five music students of the

Table 1
REBA scoring for postural risk

Postural risk	Score
Negligible risk	1
Low risk	2 or 3
Medium risk	4 to 7
High risk	8 to 10
Very high risk	11 or more

University of Guadalajara, to identify possible problems regarding clarity in the sense of the statements and terms. The final version of the questionnaire was conformed by sixteen statements: eight statements referred to self-efficacy perception and eight focused on comfort. Participants had to mention if they agreed or disagreed with each statement.

2.5. Procedure

2.5.1. Ethical considerations

Participants received all the necessary information about the procedure, verbally and through a video tutorial. Afterwards, they were informed about the objective and process of the study and were asked to sign a consent form. All of them were of legal age to sign the consent form. The activities to be accomplished in this study did not imply any risk for the participants.

2.5.2. Postural test

All participants played the musical exercise using the three guitars supports randomly assigned into three groups. Before starting the tests, with the purpose of registering anthropometric data into the

3DSSPP software, the weight and height of each of the participants were registered.

The bench was adjusted according to the participant's height, considering 90 degrees flexion in the knee joint and 90 degrees between the trunk and lower extremities. Afterwards, the metronome was programmed to 80 bpm to play two notes per beat. All musicians played the exercise 4 times to complete 4 minutes, approximately. Participants were video recorded while playing using three cameras simultaneously. (see Fig. 2). The video camera for superior view was attached to the ceiling, almost 2 meters over the participant's head. Posterior and lateral video cameras were located 1.5 meters away from the guitarist, approximately.

2.5.3. Self-efficacy and comfort test

Once finished with the exercise using one of the guitar supports, musicians had a rest period of 15 to 20 minutes before using the next auxiliary implement. During the rest time, participants answered the questionnaire about perceived self-efficacy and comfort to evaluate their experience after using every device. All participants had to play with all three devices.

2.6. Data collection and processing

2.6.1. Data for postural analysis

The final material was saved in independent folders by participant and auxiliary implement. The videos were synchronized using the trial version of Camtasia Software (see Fig. 6).

One hundred photograms per video, per participant, per auxiliary implement, saved and divided by pitch or register (high, medium and low) according to the position between the left arm and guitar's fin-

gerboard were considered. In each participant, six tests (REBA) for each auxiliary implement, two for each register (high, medium and low) were applied. In total, 54 evaluations for each auxiliary implement were made.

Then, the photogram with the highest REBA score in each register was selected to be processed using the 3DSSPP software. In the second phase of the postural assessment, it was possible to estimate torso flexion, torso axial rotation, torso lateral bending, shoulder abduction, hip flexion, humeral rotation and low back compression. With the purpose of identifying if the data collected using the 3DSSPP software showed significant differences, it was necessary to apply a statistical analysis using ANOVA considering a p -value below 0.05 for each postural parameter. The statistical analysis was considered only after normal distribution and homogeneity of variance in all measurements were confirmed. The measuring unit to estimate the differences between postural parameters were angles. Using as a reference the preset neutral sitting posture of the software (Fig. 7). The low back compression was also estimated with this software, and the measuring unit was Newtons (N), taking again as reference the preset neutral sitting posture and the NIOSH guideline limits for an acceptable job design in sitting posture to classify possible risks factors.

2.6.2. Data for self-efficacy and comfort analysis

Once all the questionnaires were answered, the results were analyzed and classified by participant and auxiliary implement. All items were identified and separated according to the variable and dimension. A frequency analysis to determine the percentage of participants who agreed or disagreed with the information was made. Based on this, the



Fig. 6. Final video in three different angles simultaneously.

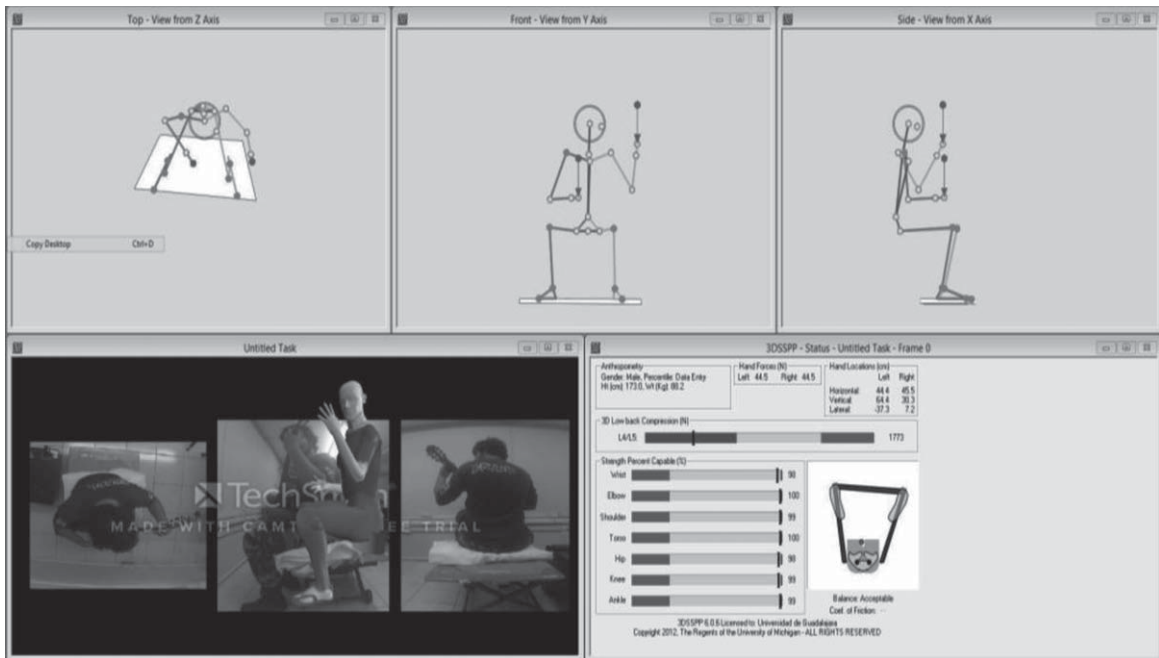


Fig. 7. Emulation of the sitting posture while playing the guitar.

differences in self-efficacy and perceived comfort among participants were identified.

3. Results

3.1. Postural analysis with REBA

The 20.4% of the assessments with the rigid lap support reported high postural risk; the other 79.6% presented a medium postural risk. The percentage was similar for the footstool, with 22.2% of the high postural risk and 77.8% of medium risk. Finally, the guitar cushion presented 27.8% of the evaluations with high postural risk. Table 1 shows the scores for postural risk classification. In all cases, the highest scores in the neck flexion, torso flexion and left shoulder abduction were registered.

3.2. Postural analysis with 3DSSPP software

A normal distribution of the quantitative data through a Shapiro-Wilk test was found ($p = \geq 0.05$). The analysis only revealed statistical differences after using the footstool in the left leg elevation (ANOVA ($p = \leq 0.05$)).

Even the supports for guitar positioning have different design and use, none of them showed to be

Table 2
Hip flexion scores

Body region	Auxiliary implement	Mean (grades)	Standard deviation
Hip flexion	Guitar cushion	91.5°	±6°
	Footstool	108.9°	±3.7°
	Rigid lap support	89.9°	±5.1°

more of an advantage regarding the musician posture. In general, the use of rigid support and the cushion cause very similar postural conditions. Nevertheless, use of the footstool generates a permanent elevation of the left hip and concentrates the bodyweight on only one ischial tuberosity, which constitutes the greater posture deviation regarding neutral posture (Table 2).

Other important posture aspects are trunk flexion, and trunk axial rotation (Table 3). During the use of the three devices, important anteroposterior and lateral movements, especially in the trunk axial rotation, were identified. These deviations were maintained during all the performance, which probably increased the postural load asymmetrically.

3.3. Self-efficacy and comfort

The evaluation of self-efficacy and perceived comfort showed that musicians had certain tendency to

Table 3
Trunk flexion and trunk axial rotation score

Posture parameter	Auxiliary implement	Deviation angles from neutral posture (medium pitch)
Torso flexion (antero-posterior)	Guitar cushion	3.5°
	Rigid lap support	4°
	Footstool	6.1°
Torso axial rotation	Guitar cushion	11°
	Rigid lap support	14.6°
	Footstool	10.8°

identify the footstool as the best auxiliary implement. In perceived self-efficacy, 100% of the participants agreed the footstool was the best device to use when they tried to play the higher notes of the guitar and when they wanted to have more visibility of the guitar's fretboard. Regarding self-efficacy, the rigid lap support and the guitar cushion reported 78% of agreement.

89% of the musicians considered they could have more confidence and better physical contact with the musical instrument when performing more complex musical pieces using a footstool. The rigid support and the cushion reported 67% of agreement. Regarding comfort and use experience, the 89% of the participants mentioned they felt more comfortable by using the footstool in comparison with the rigid lap support with 55% and the guitar cushion with 78% of the musicians. 100% of the musicians mentioned the footstool and the guitar cushion were the easiest guitar support to use. In this item the rigid lap support reported only 55% of agreement.

4. Discussion

4.1. About the postural findings

Musicians' postures during the playing of their instruments had implications on their health and performance [14]. The body posture is usually modified by physical aspects like functional and dimensional characteristics of the workstation [15–17]. The results found in this study contributed to identify the guitar supports as an important factor among the workstation, to define the characteristics of the musicians postures, being particularly affected in the lumbar zone, shoulders angles and weight distribution.

Nordin, Frankel and Forssén [18] argue that a good sitting posture is characterized by a minimum muscu-

lar exertion and an appropriate back and feet support. This posture is found in the lumbopelvic pattern, where the feet are completely supported on the floor, the thorax is relaxed, there is a neutral lordosis of the lumbar spine and there is a 90° angle between torso and legs and in the knee joint.

Certain sitting patterns have been associated with lower muscular activity and lower hip joint efforts. The lumbopelvic pattern results in smaller joint moments on the lumbar spine and also positions the lumbar spine closest to the neutral posture minimizing passive tissue stress [29]. Hence, it is expected that working postures with higher risk scores and higher deviations cause higher values of muscle activity and possibly more joint effort [30]. Musicians who play in a sitting posture cannot use their entire body to support their weight, and their ischial tuberosity bear the most significant part of it [19]. A hip flexion beyond the neutral sitting posture as found in some observations of the present study, can have negative consequences. This hip posture may cause a critical pelvic retroversion, which could lead to the development of lumbar kyphosis, asymmetric body weight distribution, and excessive muscular activation.

According to Lin, Hsieh, Cheng, Chen and Lai [20], a low postural load on the glenohumeral joint avoids the activation of many muscular groups and excessive shoulder abduction. Regarding this, lifting the guitar using the rigid support and guitar cushion, instead of raising the leg using the footstool, presents better results.

The footstool generates the biggest postural deviations which reduce the support of all weight to only one ischial tuberosity and create a more static and awkward posture in conditions to musculoskeletal disorder occurrence.

The low back compression found during the use of the three guitar supports (between 1,300 and 1,400 N) is acceptable having as a reference the NIOSH proposal which mention (3,400 N as the limit).

The supports' dimensions and adjustments appear as an important factor in defining posture deviations as found with the shortest participant where the shoulder angle abduction was the highest. Based on this, anthropometric data of 5 and 95 percentile should be considered to define supports' dimensions and adjustments range.

The guitar's arm length and the position of the left arm are two very important factors in determining the motion of the glenohumeral joint from the anteroposterior axis. Registered positions closest to the neutral posture were characterized by an alignment between

the height of the exocantion and the height of the first fret of the guitar at angles between 45° and 55° . Therefore, the design of a new auxiliary implement should facilitate a guitar inclination in the angle ranges mentioned and more physical contact between musician and guitar, to keep a neutral position of the left shoulder.

The majority of professional guitarists play their instruments for many hours a day, which in the long-term might represent a postural risk, especially for the presence of soft tissue compression. So, it is necessary that new support for guitar positioning facilitate a dynamic performance to change and minimize the tissue compression, in addition to considering comfort, anatomical, biomechanical and anthropometric characteristics of the musicians.

It's important to integrate movement into the sitting positions by changing the sitting pattern and breaking up periods of prolonged sitting. Then it could be possible to reduce the sedentary aspect of sitting [21]. These conditions are not achievable by using the evaluated supports and it should be considered as another characteristic for a new support.

4.2. About the self-efficacy and comfort perception

The footstool was the best-evaluated support, regarding self-efficacy and comfort. This result is very interesting considering the low postural qualifications registered during the use of this support. One possible explanation is related to the musicians' previous experience using similar products. Nevertheless, the high control sensation, visibility of the guitar's fretboard, confidence and the closeness location of the guitar were mentioned as relevant factors to prefer this support.

The low comfort perception using the rigid lap support could be related with the material and size of the contact zone. Based on this, the form and the material texture of the contact area should be analyzed to transmit a secure sensation while the implement is used.

Those results show the importance in considering different kinds of information and in defining design process, taking into account factors beyond postures. The user's participation during a design process could be key to improving the workstations conditions [22, 23] and to get better results in the development of new products for musicians.

In future studies, it is important to consider longer interactions between musician and guitar supports to

identify the role of the experience on the perception, using different objects for a long time.

4.3. General considerations

Some studies [24] have shown the importance of designing training programs for good health conditioning to face the demands of the musicians' activities. Sports, warm-ups, stretching, muscle strengthening exercises, and yoga have been implemented in educational programs and have shown its efficacy. Nonetheless, it is important to extend this preventive approach considering the design of coherent objects with musicians needs and expectations and adequate physical aspects of their workstations. This approach is important considering individuals' understanding of their health and how they perceive their own work capacity or self-efficacy [28].

In this regard, the present study is expected to contribute together with other studies focused on the instruments [25], the use of splints in interaction with the devices [26] or considering the furniture [18], to understand the importance of ergonomic design in the guitarist's workstation. It is relevant to mention that the design principles mentioned should be adjusted to the population where it would be applied, considering anthropometric and anatomical differences and identifying possible musicians' expectations.

4.4. Design requirements for a new implement for guitar positioning

Based on the postural analysis and self-efficacy and comfort perception, some parameters to design a new auxiliary implement were proposed. After analyzing the guitar supports, it was possible to suggest design parameters to develop a new guitar support for its positioning. One of the most important aspects considered in improving the interaction between musicians and guitar is anthropometry. Misfit dimensions between musicians and guitar supports contribute to generate risk postures and problems during musical interpretation. Other aspects to consider are visual contact with all guitar fingerboard, and guitar closeness and stability. Also, through the self-efficacy and comfort analysis it was possible to identify several aspects to improve between the musicians and instrument in terms of physical interaction. Tables 4 and 5 show these design parameters and criteria for development of a new auxiliary implement. A set of anthropometric parameters are mentioned

Table 4
Design requirements considering criteria on which they are based

	Design requirement	Criteria
1	The guitar positioner must allow both feet of the musician to be supported on the floor	– Avoid torso lateral bending – Avoid left hip flexion
2	Adjustable height. The guitar positioner must allow the first fret of the guitar to be at eye level with the guitarist	– Avoid torso flexion – Avoid hip flexion – Avoid neck flexion – Avoid excessive shoulder abduction
3	The guitar positioner must fit the anatomical area on which it rests. For example, the guitar could be located on the thigh, considering its curved shape.	– Avoid instability of the guitar positioner – Avoid ischemia by compression of body tissues
4	The size of the positioner support zone must fit the size of the anatomical area on which it rests.	– Avoid instability of the guitar positioner
5	The material of the positioner support zone should be soft and cushioned	– Avoid ischemia by compression of body tissues
6	The guitar positioner should facilitate an inclination of the guitar between 45° and 55°	– Avoid excessive shoulder abduction
7	Use a semi-rigid material or a system to tilt the guitar in different directions in a small range of movements.	– Avoid a rigid posture – Avoid excessive shoulder abduction
8	A reliable holding system to fasten the guitar, using a soft material and avoiding pressure on the instrument.	– Avoid damage on the instrument material

Table 5
Suggestions of anthropometric parameters to define the dimensions of a new auxiliary implement

Design requirement	Measurement description	Anthropometric parameter
Minimum height. The guitar positioner must allow the first fret of the guitar to be at eye level with the guitarist	The vertical distance between the seat surface and <i>exocantion</i> . Sit posture. Head and trunk in a straight line. Frankfurt plane.	Female, percentile 5
Maximum height. The guitar positioner must allow the first fret of the guitar to be at eye level with the guitarist	The vertical distance between the seat surface and <i>exocantion</i> . Sit posture. Head and trunk in a straight line. Frankfurt plane.	Male, percentile 95
Support zone size. Must be coherence between support zone size and the anatomical area on which it rests. If the chosen area is the thigh, as seen in the rigid support and the guitar cushion, is suggested to cover $\frac{3}{4}$ of its upper surface.	Thigh perimeter.* Sit posture — thigh perimeter took in the center of the thigh.	Male, percentile 95 **

*Thigh perimeter is used as an example. The fit between support zone size and the anatomical area which it rests will depend on the design of the implement. **Percentile 95, male was chosen because the biggest perimeter was found in this gender. Nevertheless, it could be different in other populations.

considering interaction between guitar supports and guitarist and neutral posture (see Table 5).

4.5. Limitations

This study was limited by the small number of participants. Additionally, the male population constituted the majority of participants and it is possible that women's physical characteristics and perception define other circumstances in the interaction with the guitar supports. Another limitation is related to the participants' experience as musicians and as product users. Considering different years of experience and allowing musicians a more extended interaction with the guitar supports could diminish a possible bias

in their perception regarding guitar supports. Finally, it is important to broaden the study perspective to analyze the guitarist activities as a system, considering other components, needs and interactions in the guitarist workstation.

5. Conclusions

It is essential to understand the guitarist's work happens within a complex system. There are different aspects related to furniture and guitar supports which could affect the musician's health directly. Based on this idea, the guitarist's workstation should be designed, considering different needs and requirements to diminish the risk factors.

Other important aspects are the musicians' perception and expectations, based on their experience and needs during practice and presentations. The results suggest that the implement which generates the highest risk factors was the most preferred too, which could be related to the guitarist experience. In this sense, the experience could define the use of specific guitar supports, even though those devices wouldn't be the best option.

The musicians' anthropometric characteristics must be considered to define the workstation' dimensions. Differences between populations and genre are crucial aspects of designing adequate workstations. It is expected that the design requirements proposed in this study contribute to improve the design process and avoid ergonomic risk factors. Nevertheless, it is crucial to continue the analysis. A study with more participants and with different levels of experience should be considered to get more information and to increase the requirements' reliability.

Conflict of interest

None to report.

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