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Postural and dynamic analysis of the human body: The relevance of the functional modulator factors in the methodological design

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Abstract

Functional studies analyze the interaction between the human body and its environment studying both, the posture and the movement. It is well known that at the Universities where health science and sports studies are taught there is a need to raise academic activities involving functional studies.

The main objective is to make awareness of the factors that can modulate a certain function in the human body and must be well known for university students to perform a good research projects and career. To do this, we present a detailed list of intrinsic and extrinsic functional modulator factors (FMF) of the human body and propose a new methodology to teach those skills. During both, the project data collection and data reduction, FMF such as sitting and standing postures or walking, running and jumping movements must be taken into account. The recognition of the FMF that may influence the results must be previously known and identified to succeed in the methodological design of functional studies of the human body.

The novelty of our work is not to direct the attention to the lecturer but to focus it to the student's academic support to accomplish the active work like the fieldwork presented in this paper. In conclusion, the understanding of the FMF by university students using fieldwork activities during their degree would help them to develop a critical attitude in terms of validity and scientific evidence.

Keywords

Modulating factors, function, posture, movement, methodology

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1. Introduction

One of the fundamental and primary human principles is to control our environment, to achieve this, you must perform certain functions. Among the most important non-vital functions of the human being is the postural control including seating, standing and the dynamic control named walking, running or jumping (Cano **et al**. 2012). In fact, posture and movement are not different entities, understanding standing as a posture movement and movement as a quick succession between different positions (Trew **et al.** 2006).

Both, movement and posture involve a huge amount of information to be properly processed by the nervous system. The integration of the information and the motor responses are very complex, this do not only require a sophisticated network of neuronal connection between the different structures of the central and peripheral nervous system, but also involve other body systems. The efficient and adapted functions performed by the central and peripheral nervous system, muscles, joints, and the skeleton, and their actions in the context of movement, is known as neuromotor control (Shumway-Cook **et al.** 2007).

Since the neuromotor control of postural support and locomotion is dependent on many variables that can modulate and alter the stability and progression of the human body it is essential to control these variables in all functional analysis of the human body. All these variables are functional modulator factors (FMF), which can be divided in intrinsic and extrinsic FMF (Collado, 2002). Intrinsic factors refer to any conditions that are specific to the subject as a unique and particular individual, whereas extrinsic factors are physical aspects that directly affect the biomechanical behavior of the human body.

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2. Proposed methodology: integration of different teaching methods

The proposed methodology will be developed in a biomechanics course which is offered during the second year of the Physiotherapy Degree. This course consists of 6 European Credit Transfer and Accumulation System (ECTS credits) where contents on tissue, joint biomechanics and kinesiology biomechanics are studied. The aim of this course is to develop the following competencies in the students:

1. Teamwork.
2. Oral communicative skills.
3. Critical skills.
4. To know and understand the sciences, models, techniques and tools in which physical therapy are built.
5. To assess the patients' functional status.

Almost half of the credits of this course (2.5 ECTS) will be devoted to the functional study of human walking. To work these concrete contents and develop the general skills that must be achieved during the course, a set of activities are raised. These activities are oriented around FMF that can modify the function analysis of human walking and must be controlled during the study. These activities will be:

1. Master class.
2. Tutorials.
3. Watching and hearing documents.
4. Fieldwork.
5. Oral presentation.

6. Problem-based learning (PBL).

7. Exams.

Using the individual marks for each activity, the final record of the Biomechanics subject will be calculated as follows:

Record = (20% Fieldwork) + (20% Oral presentation) + (20% PBL) + (40% exams)

2.1. Methods with high implication of lecturer

2.1.1. Master classes

The main objectives are: 1) to known the different existing FMF and classify them according to their intrinsic and extrinsic nature; 2) to be able to understand how the FMF can influence the functional analysis.

The main competencies to be developed by the student are:

- The ability to recognize the FMF.
- To be able to control this FMF in the methodological design of human functional studies.

➢ **Intrinsic functional modulator factors**

  - Age

There are few periods over the human development in which the behavior is different depending on the biological age of the subject. Following the acquisition of walking abilities around 12 months of age the central nervous system is still in maturation. It is considered to be at the age of 5-7 years when the anthropometric and the biomechanical differences between children and adults disappears (Kirtley 2006; Viel et al. 2002; Sutherland **et al.** 1988; Sutherland, 1997; Shumway-Cook **et al**. 2007). It has been shown that the static balance and motor synchronization improves with age in children at the age of 5 to 12 years (Geuze, 2003; Debrabant **et al.** 2012). Moreover, during adolescence it does not exist a linear relationship between the spatiotemporal parameters of human walking and age because there is a peak in bone growth which unbalances the neuromotor control (Shumway-Cook **et al.** 2007; Schmidt **et al.** 2005). Finally, in adults above 65 years old, human gait decreases in speed, in stride length and joint range and increases in cadence, in bipodal support, variability in muscle activity and energy cost (Perry **et al.** 2010; Whittle, 2002; Kirtley, 2006). It is still unclear whether the variation of these parameters is due to the alterations in the musculoskeletal system or as a result of the slower gait seen in the elderly population (Oatis, 2009). Even so, there is consensus that the quality of static and dynamic functions decreases with age (Hernandez **et al.** 2012; Huang **et al.** 2013).

- Gender

Although it is considered that women walk with more cadences and less length stride it has been shown that these differences disappear when it is normalized by the anthropometric data of each sex population (Oatis, 2009; Nerín et al. 1999). However, previous studies have revealed small gender differences in the movement of pelvis and trunk during walking; man**'s** trunk is moved more laterally while women preserve the verticality but moves more her hips during walking (Dufour **et al.** 2006). In addition, men maintain the arms more static than women during walking (Li **et al.** 2001). In relation to sports there are also some differences in postural control between genders (Ku **et al.** 2012), women presents minor movements of postural balance during sports (Greve **et al.** 2013). The small differences found between men and women during human gait have not been found in children (Kirtley, 2006; Viel et al. 2002; Sánchez et al. 1999; Sutherland et al. 1988; Sutherland, 1997; Nerín et al. 1999).

- Racial and cultural

Although specific features are due to the human race and the three biotypes, there is no evidence that any of these factors could modulate differential functional behaviors. However, the cultural behaviors of a particular social group may determine the gait pattern, as in Japanese culture in which giving small steps is appreciated as a value of elegance (Collado, 2002).

- Mass

According to the first law of Newton, the stability of a body is conditioned by their weight. The human body is not an exception, thus postural stability improves when it has a greater mass (Méndez, 2006). When a disturbance destabilizes a heavy body in standing, a greater muscular work is required in order to control the center of mass and maintain the postural stability (Méndez, 2006; Shumway-Cook **et al.** 2007). It is also known that a given disturbance destabilizes more easily light bodies than heavy ones (Joshi **et al.** 2008). Furthermore, it has been shown a worse postural control in children with obesity due to the mismatch between the rate of fat and muscle mass in terms of force generation (D'Hondt **et al.** 2008; McGraw **et al.** 2000).

- Height

Body height modifies the baseline parameters of human walking (Perry **et al.** 2010; Kirtley, 2006; Whittle, 2002; Vaughan **et al.** 1999; Viladot, 2000; Viel et al. 2002). A shorter human body walking at the same speed than a taller one, will show a higher cadence to compensate the reduced stride length. Referring to the angular level, an increased rotation of the shoulder and pelvic girdles in anthropometrical shorter subjects will also be appreciated (Collado, 2002).

- Musculoskeletal system

Together with the visual, vestibular and somatosensory system, the mechanical state of the musculoskeletal system can affect the neuromotor control of the posture and

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movement (Westcott **et al.** 1997). The main musculoskeletal problems can be grouped into muscle weakness alterations, loss of range of joint mobility and postural and articular misalignment (Shumway-Cook **et al.** 2007).

- Fatigue

The muscles motor activity and the concomitant generated force are conditioned by the availability of energy. When this energy is deficient fatigue starts. Fatigue is a multifactorial state that must be controlled to avoid an asymmetric posture (Paillard **et al.** 2013; Viner et al. 2008), Fatigue, cannot be controlled with only one variable (Suay **et al.** 1998).

- Nervous system

To ensure a good body stability and orientation of all his segmental components during an activity by the neuromotor control (Woollacott **et al.** 2005; Woollacott et al. 1998; Rama López **et al.** 2003), an adequate motor strategy together with an integration of the visual, vestibular and somatosensory system is required (Alemán **et al.** 2003; Martín **et al.** 2004; Rama López **et al.** 2003). The integrity of the nervous information ensures an appropriate movement pattern and postural stability to guarantee an appropriate adaptation of the body to the environment (Shumway-Cook **et al.** 2007). It is also required a healthy peripheral nerves which can transport the somatosensory afferent information to the spinal cord and to higher centers, and later on to transmit the efferent or motor impulses to the relevant muscular system (Wiebers **et al.** 2007).

- Cognitive-perceptual dimension

The gait functionality is governed by technical and biomechanical constraints but is heavily managed and influenced by mental parameters such as fear of falling or other feelings of insecurity (Shumway-Cook **et al.** 2007). The individual psychological conditions influences the neuromotor control in general and the postural control in

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particular (Trew **et al.** 2006). Zok et al. (2008) have previously shown how the posturographical records were altered in subjects with a simple change in the instructions, showing less stability when participants were asked to "to stay standing quietly" versus a the second statement which was "to stand as still as possible". Personality and mood varies between subjects and influences directly to the human gait (Collado, 2002 and Shumway-Cook **et al.** 2007).

- Attention

The human being has a very low level of awareness of the movements performed daily to carry out various human functions successfully. Movements that initially have been learned with a high level of willingness, end with an automatic and unconscious execution (Trew **et al.** 2006). Controlling the standing and walking are considered automatic activities, nevertheless, numerous investigators have demonstrated that it can be highly influenced by the conscious part of the brain (Blanchard et al. 2005; Tiernan **et al.** 2008; Zaino **et al.** 2008; Rankin **et al.** 2000; Brown **et al.** 1999; Tomita et al. 2010).

- Experience and motor learning

Motor learning is an adaptive and an internal processes that associated with the practice and experience can lead to a relatively permanent changes in the ability to produce motor activities and behavior (Abernethy **et al.** 2005; Schmidt **et al.** 2005). There are different types of learning: The simplest way is the habituation or non-associative learning, which consist in the integration of a single action (Bertoti, 2004), the complex way is the associative learning which consist in learning a new task that requires its repetitive practice (Shumway-Cook **et al.** 2007). In conclusion, the reproducibility and repeatability of a particular task or function is conditioned by the prior and practical notion we have of it.

- Pain

http://dx.doi.org/10.4995/muse.2015.3754
ISSN: 2341-2593

Pain is an unpleasant sensory and emotional experience associated to a present or potential injury (Ibarra, 2006). The physical pain response is immobilization and protection of the painful area to avoid more stress to the involved tissues (Trew **et al.** 2006). During a painful walk it can be seen a reduction of the load intensity, the time of support and an inactivation of the joint mobilization, stretching and muscle activation (Sánchez et al. 1999; Perry **et al.** 2010). Since the presence of pain is not always verbalized by the subject, especially by children, it is recommended to ask explicitly about the presence or absence of pain (Hicks **et al.** 2001). Although pain involves a subjective perception is convenient to quantify it using numeric, visual or analog scales (Quiles **et al.** 2004).

- **Extrinsic functional modulator factors**

    - Ground

Firstly, ground type influences the reaction force so the impacts increase with increasing pavement hardness. Moreover, the inclination of soil influences human posture and gait. Secondly, when walking on a flat ground one leg has an accelerator role and the contralateral leg has a decelerator role interspersed with steps, while walking on slops both legs involved in the same function. Also, the stride length is inversely proportional to the slope. Specifically, when the slope is ascending the body leans forward and foot plays a predominant propulsive function in the lower extremity. In contrast, when the slope is downward body leans back and foot is in equines playing a braking role in the lower extremity. In the event that the slope inclination is lateralized, body leans towards the higher side, placing the foot on that side in eversion and the most fallen in supination (Collado, 2002).

    - Footwear

http://dx.doi.org/10.4995/muse.2015.3754
ISSN: 2341-2593

There are many different kinds of shoes, according to its material and design, or according to the sport or activity carried with them. Shoes can produce either beneficial biomechanical effects (cushioning and protection) or undesired effects (articular or postural alterations). The use of heels in standing, shifts the subject's mass center forward flexion and increases across the lower extremity, pelvic anteversion and lumbar lordosis, while in walking heels reduces step length and gait speed (Rueda, 2004; Sánchez et al. 1999).

- Clothing

Apart from the convenience of using lightweight and tight clothes for gait observation (Perry **et al.** 2010; Kirtley, 2006), clothing can influence gait pattern. For example, a heavy coat induce the subject to walk hunched forward or a narrow skirt forced to do a shorter steps and a higher cadence (Collado, 2002).

- Base of support

Every solid body not in suspension is held by support points delimiting a surface on the floor; this is the base of support (BoS) (López **et al.** 2003; Oatis, 2009). The spatial relationship between the body base and its base of support set the stability of the body. In order to study this ratio the body center of mass (COM) should be determined and the vertical line of force should be projected, the balance will be found when the force falls within the center of the polygon (López **et al.** 2003; Ferdjallah **et al.** 2002).

- Center of mass

When the position of the center of mass descends being closer to the ground, the stability of the body increases, and conversely (Méndez, 2006). The stability of a posture like standing and the dynamic control of a skill like driving, are related to the relationship between the position of the center of mass and central limits of BoS (de Graaf-Peters et al. 2007; Peydro de Moya **et al.** 2005; Baydal-Bertomeu et al. 2004).

http://dx.doi.org/10.4995/muse.2015.3754
ISSN: 2341-2593

- Segmentation

The stability of a column consisting of different parts or segments is more complex than others formed by a single piece (Méndez, 2006). The stability of a multi-segmented column such as the human vertebral column, can improve when the segments are positioned into the vertical (Méndez, 2006; López **et al.** 2003; Dufour **et al.** 2006).

- Speed

The walking speed increases with the increase of: 1) the cadence; 2) the stride length; 3) the variability in the steps amplitude; 4) the joint range of joints; 5) the ground reaction forces; 6) the intensity of muscle activity; 7) work and power in all joints of the locomotive unit; 8) the extent of vertical and horizontal displacement of the center of mass (Oatis, 2009; Grieve **et al.** 1966; Damiano **et al.** 2006; Johnston et al. 2011; Perry **et al.** 2010; Kirtley, 2006; Whittle, 2002; Viel et al. 2002; Sánchez et al. 1999; Gage **et al.** 2009; Vaughan et al. 1999).

- Friction

A good firmness between tangential forces of the support areas and the contact surfaces, improves the stability of the body, in the way that, when friction increases, stability increases (Méndez, 2006; Hewitt, 2004).

- Loads

During daily routines we often loads different weights that are distributed and grasped in different ways (Collado, 2002). When the human body interacts with a heavy load the center of mass is shifted towards the load to stabilize the new disturbance (Horak **et al.** 1986). For example, when we are carrying a loaded backpack onto the back, the oscillations of the higher center of masses are minimized, reducing the shoulder movement, the pelvic girdle and the arms swing while walking (Collado, 2002).

http://dx.doi.org/10.4995/muse.2015.3754
ISSN: 2341-2593

2.2.2. Tutoring

Tutorials are optional and can be performed individually or in groups not exceeding 10 students. Students must attend with concrete and properly prepared doubts according to the content of the previous lectures. Therefore, the main objective for both the teacher and the student is to clarify any doubts or complete any information gaps.

2.2. Methods with high implication of the student. Independent work.

2.2.1. Document viewing and listening

Students should watch certain documents that are linked to class content in websites, blogs and videos recommended by the teacher in addition to the master class assistance.

2.2.2. Fieldwork activity

Fieldwork will be done by 3 or 4 students as teamwork. It will consist in recording the human gait of 4 subjects who will be walking freely following a scientific validated methodology in terms of technique and biomechanics.

The objective of this activity is to consolidate the theoretical knowledge of all FMF studied in class in a real human walking kinematic analysis example. Each team can choose a specific FMF and perform a functional analysis analyzing variations in this factor. For example, if the variable "speed" is chosen, 4 subjects will be recorded walking firstly at a slower speed and then at a faster speed, afterwards the team will have to analyze the kinematic parameters and study how are they altered by changes in speed.

The work will be presented on CD or DVD with the following documents: 1) the informed consent of the 4 participants; 2) recorded and edited videos (3 replicates for each condition and participant); 3) statistical analysis; 4) a detailed document containing the hypotheses, the study design, the results and the main conclusion; 5) the oral presentation file.

http://dx.doi.org/10.4995/muse.2015.3754
ISSN: 2341-2593

In this project, the students will be offered the possibility to record the video in a cinematic laboratory whit the researchers support. This will allow us to have both:

The experimental group ⇒ university students who performs the records in the kinematic laboratory.

The control group ⇒ students who record the video elsewhere without additional educational support.

2.2.3. Oral presentation

All the team members must actively participate on the oral presentation of their own fieldwork. The maximum exposure time is 5 minutes and the use of English will be positively evaluated.

2.2.4. Problem based learning (PBL)

It consists in solving 10 practical problems or case studies in small groups and with the teachers' support. The aim is to actively work on the theoretical knowledge taught in the master class. Finally, these PBL will be interactively solved with the teacher.

http://dx.doi.org/10.4995/muse.2015.3754
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2.2.5. Exams

Five on-line type test exams will be set to perform with the help of students' notes. The aims of these written tests are: 1) to evaluate the knowledge acquired by students and 2) to stimulate a continuous students learning.

Results

In this study there were 133 students included in the control group and 48 students included in the experimental group. Qualification records for each activity according groups are shown in Table 1 and Table 2 for all the studied subjects (n=188).

Table 1: Qualifications of the studied subjects.

	All Students	Control Group	Experimental Group	p-value
N	181	133	48	--
PBL	6.78 ± 1.89	6.91 ± 1.51	7.38 ± 1.11	0.058
Oral Presentation	7.09 ± 2.17	7.42 ± 1.50	7.88 ± 1.10	0.071
Fieldwork activity	7.54 ± 2.02	7.72 ± 0.94	8.63 ± 0.79	**p<0.0001**
Final Exam	6.76 ± 1.91	6.98 ± 1.45	7.33 ± 1.18	0.172
Final Record	7.00 ± 1.73	7.20 ± 1.00	7.71 ± 0.75	**0.001**

Data are shown as mean and standard deviation. PBL: Problem Based Learning. P values are from Mann-Whitney U test.

http://dx.doi.org/10.4995/muse.2015.3754
ISSN: 2341-2593

Table 2: Fieldwork activity qualifications of the studied subjects.

	All Students	Control Group	Experimental Group	p-value
N	181	133	48	--
Informed Consent Collection	0.91 ± 0.22	0.89 ± 0.24	0.96 ± 0.14	0.081
Work Presentation	0.88 ± 0.17	0.88 ± 0.17	0.88 ± 0.17	0.975
Bibliography Used	0.33 ± 0.39	0.29 ± 0.38	0.44 ± 0.39	**0.016**
Introduction	0.42 ± 0.37	0.42 ± 0.34	0.41 ± 0.43	0.851
Hypothesis and Objectives	0.95 ± 0.12	0.95 ± 0.12	0.95 ± 0.09	0.649
Data Collection Quality	3.97 ± 0.86	3.62 ± 0.72	4.96 ± 0.14	**p<0.0001**
Data Reduction	2.49 ± 0.52	2.42 ± 0.52	2.67 ± 0.44	**0.003**
Data Presentation	0.89 ± 0.28	0.96 ± 0.11	0.71 ± 0.46	**0.005**
Data Interpretation	0.97 ± 0.10	0.96 ± 0.11	0.98 ± 0.05	0.402
Final work	4.12 ± 0.69	4.05 ± 0.71	4.30 ± 0.63	**0.033**

Data are shown as mean and standard deviation. P values are from Mann-Whitney U test.

Students included in the experimental group showed 1 more point in average of the fieldwork activity ($p<0.0001$) and 0.5 more points in average of the final record ($p=0.001$) than the students included in the control group. No differences were seen in the problem based learning activities, the oral presentation or the final exam records (Table 1; Figure 1).

Multidisciplinary Journal for Education, Social and Technological Sciences
http://dx.doi.org/10.4995/muse.2015.3754
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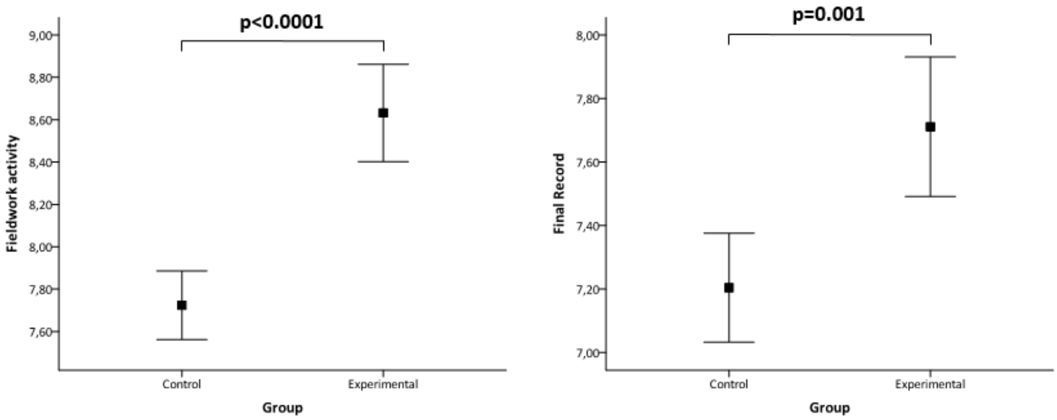

Figure 1: Qualifications of studied subjects according to groups (n=181). Graphs represent error bars. P values are from Mann-Whitney U test.

Taking into account only the records of the fieldwork activity, four factors 1) the bibliography used (p=0.016); 2) the data collection quality (p<0.0001); 3) the data reduction (p=0.003) and 4) the data presentation (p=0.005) significantly differed between groups, and concomitantly, the final work qualification (p=0.033). No differences were seen in the records obtained for the informed consent collection, the work presentation, the introduction, hypothesis and objectives and finally, the data interpretation (Table 2; Figure 2).

Multidisciplinary Journal for Education, Social and Technological Sciences
http://dx.doi.org/10.4995/muse.2015.3754
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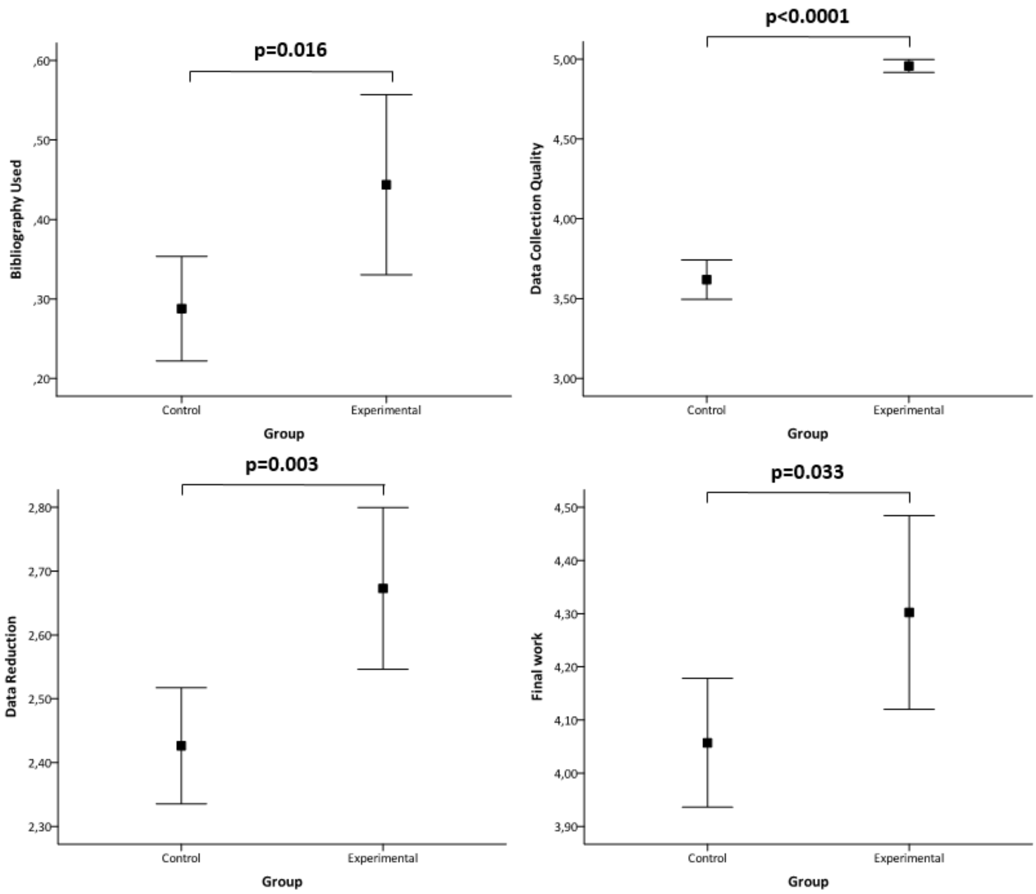

Figure 2: Fieldwork activity qualifications of studied subjects according to groups (n=181). Graphs represent error bars. P values are from Mann-Whitney U test.

4. Conclusions

The academic results of the biomechanics course were satisfactory in general but shown better performance in the group of students who have enjoyed greater academic support during the data collection in the fieldwork activity.

While there are other works that have their own indicators of superior academic performance and in which the need to increase financial resources for the improvement of the academic performance is reported (Garbanzo-Vargas, 2007; Jara et al., 2008) the novelty of our work is not to direct the attention to the lecturer actions but to focus the academic support to the active work of the students like the fieldwork we have presented in this paper.

Moreover we suggest that academic reinforcement could be done by fellows who have previously participated as student in the fieldwork and to set strategies to develop a constructive and cooperative approach for the active learning of the student.

Although the lecturer and principal author of this study is who has evaluated the student's activities, the academic support was offered by a second lecturer who not corrected the fieldwork activities nor participated in the preparations of this paper.

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