Stress response in Sport Sciences OSCE • e068006
DOI: https://doi.org/10.14195/1647-8606_68_6

Autonomic stress response in Exercise and Sport Sciences degree students in the scenarios of an Objective Structured Clinical Examination

Valentín Emilio Fernández-Elías[1], Beatriz Martínez-Pascual[2], Álvaro Bustamante-Sánchez[3], Silvia Fernández-Martínez[4], Cristina González--de-Ramos[5], Ana Ramírez-Adrados[6], Vicente Javier Clemente-Suárez[7] and Silvia Burgos-Postigo[8]

Abstract

The present study aimed to assess the autonomic stress response of Exercise and Sport Science degree students during their 12-scenario Objective Structured Clinical Evaluation (OSCE). Eighty-eight students, randomly assigned to an initial OSCE scenario, had their heart rate variability (HRV) monitored during the 12 OSCE scenarios. HRV in its temporal, frequency, and non-linear domains was analysed. Results showed a significant autonomic stress response that persisted throughout the entire evaluation without notable changes between scenarios. The heart rate response significantly differed in two scenarios compared to a break station and a written scenario ($p < .05$). However, the sympathetic

1 Universidad Rey Juan Carlos, Research Center in Sport Science, Madrid, Spain. Email: valentin.fernandez@urjc.es. ORCID: https://orcid.org/0000-0002-1459-5442.

2 Universidad Europea de Madrid, Faculty of Medicine, Health and Sports, Madrid, Spain. Email: beatriz.martinez@universidadeuropea.es. ORCID: https://orcid.org/0000-0001-6589-9369.

3 Universidad Europea de Madrid, Faculty of Medicine, Health and Sports, Madrid, Spain. Email: alvaro.bustamante@universidadeuropea.es. ORCID: https://orcid.org/0000-0002-4183-3004.

4 Universidad Europea de Madrid, Faculty of Medicine, Health and Sports, Madrid, Spain. Email: silvia.fernandez@universidadeuropea.es. ORCID: https://orcid.org/0000-0002-8561-409X.

5 Universidad Europea de Madrid, Faculty of Medicine, Health and Sports, Madrid, Spain. Email: cristina.gonzalez2@universidadeuropea.es. ORCID: https://orcid.org/0000-0002-4163-884X.

6 Universidad Europea de Madrid, Faculty of Medicine, Health and Sports, Madrid, Spain. Email: ana.ramirez@universidadeuropea.es. ORCID: https://orcid.org/0000-0001-9146-879X.

7 Universidad Europea de Madrid, Faculty of Medicine, Health and Sports, Madrid, Spain. Email: vctxente@yahoo.es. ORCID: https://orcid.org/0000-0002-2397-2801.

8 Universidad Europea de Madrid, Faculty of Medicine, Health and Sports, Madrid, Spain. Email: silvia.burgos@universidadeuropea.es. ORCID: https://orcid.org/0000-0003-4195-521X

Received on 16-02-2024 and approved for publication on 16-06-2025.

and parasympathetic modulation remained stable across all scenarios. The OSCE method proves to be a practical tool for assessing the competencies and skills of Exercise and Sport Sciences students. Additionally, HRV analysis allows teachers to evaluate students' autonomic stress responses and modify OSCE scenarios to enhance student performance.

Keywords: autonomic stress response; heart rate variability, objective structured clinical evaluation, university studies, Exercise and Sport Sciences.

Resposta autonómica ao stress em estudantes do curso de Educação Física e Ciências do Desporto nos cenários de um Exame Clínico Estruturado Objetivo

Resumo

O objetivo do presente estudo foi avaliar a resposta autonómica ao stress de estudantes do curso de Ciências do Desporto e da Actividade Física durante a sua Avaliação Clínica Estruturada Objetiva (OSCE) de 12 cenários. Oitenta e oito estudantes, designados aleatoriamente para um cenário inicial da OSCE, tiveram a sua variabilidade da frequência cardíaca (VFC) monitorizada durante os 12 cenários da OSCE. Os domínios temporais, de frequência e não-lineares da VFC foram analisados. Os dados mostraram uma forte resposta autonómica ao stress dos estudantes, mantida ao longo de toda a avaliação, sem alterações significativas entre os cenários. A resposta da frequência cardíaca variou significativamente em dois dos cenários, em comparação com uma estação de intervalo e um cenário escrito ($p < .05$). No entanto, a modulação simpática e parassimpática não se alterou ao longo dos cenários da OSCE. A metodologia OSCE é uma ferramenta adequada para avaliar as competências e aptidões dos estudantes de Educação Física e Ciências do Desporto. Além disso, a análise da VFC permite que os docentes avaliem a modulação autonómica do stress dos estudantes e adaptem os cenários da OSCE para melhorar o desempenho académico.

Palavras-chave: resposta autonómica ao stress; variabilidade da frequência cardíaca; avaliação clínica estruturada objetiva; estudos universitários; Educação Física e Ciências do Desporto

INTRODUCTION

Regarding University studies, since the Bologna Declaration, there has been an important modification in the learning and evaluation methods in higher education that emphasizes the active training of students evaluated by the acquired competencies (Cano García, 2008). For this reason, new evaluation processes have been developed to assess whether students acquire the abilities and skills required for their careers. One of these methodologies is the Objective Structured Clinical Examination (OSCE), which was first described by Harden in 1975 (Harden et al., 1975) to improve the validity and reliability of the assessment of performance. The OSCE has been proven to be a valid and reliable tool that can assess the three learning domains (cognitive, affective, psychomotor) and the highest level described in the Miller pyramid: the "shows how" (Carraccio & Englander, 2000; Miller, 1990; Newble, 2004; Sloan et al., 1995).

In the last thirty years, the OSCE has grown exponentially worldwide in undergraduate and postgraduate examinations (Khan et al., 2013). So far, the OSCE has been mainly used in health sciences fields such as medicine, nursing, psychology, midwifery, dentistry, and physiotherapy. However, other areas of knowledge have begun to adapt the OSCE, as it serves as a model for social work students (Bogo et al., 2011); however, the presence of OSCE in social sciences appears to be scarce. Previous research has proven that some challenging academic events, such as OSCEs (Bellido-Esteban et al., 2021; Martinez-Pascual et al., 2022), final project oral defence (Ramirez-Adrados et al., 2020), chemical laboratory practices (Redondo-Flórez & Clemente-Suárez, 2022), or simulation lab practices (Espejo-Antunez et al., 2022; Starcke et al., 2016) produce a large anxiogenic response in students. OSCEs are a source of novelty and uncertainty that confront students with a simulated situation they are not familiar with, increasing self-confidence in their practice but provoking stress due to their complexity and limited time to work it out (Bagheri et al., 2012). When a stimulus is interpreted as threatening by the organism, a complex autonomous nervous system response is activated, activating the sympathetic autonomous nervous system and the hypothalamic-pituitary-adrenal axis, increasing the production of cortisol, adrenaline, and noradrenaline (Hood, 2015; Morgan et al., 2006). These responses, even unconscious, could induce structural and functional changes in the nervous system, altering the executive function´s performance (Clemente-Suarez & Robles-Perez, 2013) and memory (Delgado-Moreno et al., 2017; Delgado-Moreno et al., 2019), factors that emphasise the importance of control and monitoring of the stress response in academic environments (Beltran-Velasco et al., 2020; Mendoza-Castejon & Clemente-Suarez, 2020). In this line, monitoring autonomic modulation through heart rate variability

(HRV) to analyse stress response represents a novel methodology applied across various environments, including health, education, sports, and the military. The use of portable devices to monitor heart rate is nowadays widely used, providing us with real-time information on autonomous modulation by the analysis of the HRV (Beltran-Velasco et al., 2018; Tornero-Aguilera & Clemente-Suarez, 2018). This is essential to analyse the effect of psychophysiological stress response on academic achievement and could help to develop intervention programs to improve students' coping with these challenging situations. These could include mindfulness training, biofeedback, emotional regulation workshops, or simulation-based coping strategies, aiming to reduce academic stress and enhance performance.

To the best of our knowledge, there is no previous research that analyses the autonomic stress response in Sport Sciences undergraduate degree students, despite the importance that this has in these very practical studies and where the interpersonal relationship is so important. For this reason, we conducted the present research with the aim of studying the autonomic stress response of Exercise and Sport Sciences Degree students in the scenarios of an objective structured clinical examination. We hypothesized that (i) students' autonomic stress response would be high during the OSCE and (ii) students' sympathetic and parasympathetic responses would differ according to the competencies demands of each scenario. This relevance is due to the constant interaction of sport professionals with clients, athletes, and colleagues, which requires emotional intelligence and communication skills, especially under stress.

METHOD

Participants

The students who participated in the present study were in their final year of the Exercise and Sport Sciences degree and were enrolled in a course named Practicum and the OSCE as part of their evaluation. Hence, a convenience sample of 88 students (72 men and 16 women) was enrolled. All the students who participated in the study had the same previous experience and knowledge before the beginning of the OSCE; thus, a shared starting point in the competencies of all of them was assumed. Also, as inclusion criteria, all the students were in their last year (approving the OSCE means the end of Degree studies) and none of them had cardiovascular conditions. All the participants were fully informed and gave their written consent.

Procedure

The present study was an observational research of the autonomic response in Exercise and Sport Sciences degree students throughout their OSCE. The evaluation event was performed in the Faculty of Exercise and Sport Sciences of the University. The OSCE consisted of 12 scenarios, where students were randomly assigned by the OSCE coordinator in alphabetical order by last name. From their assigned scenario, students then rotated among the remaining scenarios in ascending order. The procedure was approved by the University Ethics Committee (CIPI/22.288) and followed the Declaration of Helsinki. All participants gave written informed consent.

Before the beginning of the OSCE, a heart rate monitor (V800, Polar, Kempele, Finland) was placed on every student's chest. Once the OSCE began, students had 10 minutes to resolve the situation, using only the information they had read previously to each scenario for 2 minutes, and the skills and knowledge they acquired during their degree. Scenarios were separated by 3 minutes (1 to rest and 2 to read the information of the following scenario).

The OSCE analysed consisted of the following scenarios (scenarios are named as S and the subsequent number, e.g. Scenario 1 is S1): S1: conflict management in team sport; S2: educational adaptation of a physical education class for low skills children (non-interactive written scenario); S3: resting time; S4: physical education class design (non-interactive written scenario); S5: exercise training planning and design; S6: sport facility management; S7: management of underperforming athlete; S8: resting time; S9: facing student's parents' conflict; S10: physical exercise design in wellness context; S11: sport center human resources management; S12: physical condition assessment. This OSCE was designed to simulate authentic professional challenges in sports and exercise sciences, from interpersonal conflicts to technical planning. The scenarios were created as examples in different professional areas such as teaching, sports training, and sports management.

Measurements and instruments

Heart rate variability was registered to evaluate the autonomic stress response of the students using a validated (Giles et al., 2016) Polar V800 heart rate monitor (Polar, Kempele, Finland). Subsequently, the R-R intervals were examined with the Kubios HRV software (v3.0, Biosignal Analysis and Medical Imaging Group, University of Kuopio, Finland). We assessed HRV through the time-domain, frequency-domain, and nonlinear spectrum variables. Time-domain metrics reflect overall variability, frequency-domain metrics assess sympathetic-parasympathetic balance, and non-linear parameters indicate system complexity and unpredictability.

Time-domain variables:
– HRmin: minimum heart rate
– HRmax: maximum heart rate
– HRmean: mean heart rate
– RMSSD: the square root of the average of the sum of the differences squared between normal adjacent R-R intervals
– PNN50: the percentage of differences between normal adjacent R-R intervals greater than 50 ms

Frequency-domain variables:
– LF: the low-frequency band in normalized units
– HF: the high-frequency band in normalized units
– LF/HF: the ratio between low and high frequency band.
Nonlinear spectrum variables:
– SD1: the sensitivity of the short-term variability
– SD2: the sensitivity of the long-term variability

Statistical analysis

Data are presented as mean ± standard deviation (SD). Normal distribution of data was revealed through the Kolmogorov-Smirnov test. Thus, data were analysed using one-way analysis of variance with repeated measures (ANOVA). After a significant F-value (Greenhouse–Geisser adjustment for sphericity), pairwise differences between means were identified by using the Bonferroni post hoc procedure. The effect size was estimated by calculating partial eta squared (η2p). The level of significance was set at P-value ≤0.05. All statistical analyses were performed using the IBM Statistical Package for the Social Sciences (SPSS) software version 24.0 for Windows.

RESULTS

Data results and analysis are shown in Table 1. It stands out that statistical procedures revealed that HRmin of students was significantly higher in S1 compared to S4, and HRmed was higher in S1 compared to S3 and S4; and lower in S4 compared to S12 (all p <.05). No other significant differences were found among the OSCE scenarios in any of the variables analysed.

Table 1

Changes (Mean ± SD) in the autonomic stress response of Exercise and Sport Sciences Degree students during the OSCE.

	Time domain					Frequency domain			Nonlinear	
	HRmin (bpm)	HRmax(bpm)	HRmed (bpm)	RMSSD (ms)	PNN50 (%)	LF/HF (n.u.)	HF (n.u.)	LF (ms)	SD1 (ms)	SD2 (ms)
Scenario 1	65.60 ± 10.37	116.12 ±21.07	85.58 ±14.84	45.32 ±23.60	17.82 ±13.36	3.47 ±2.08	72.60 ±11.90	27.34 ±11.89	32.06 ±16.69	74.09 ±24.94
Scenario 2	63.08 ± 9.84	111.61 ±15.53	80.12 ±12.99	47.98 ±24.85	20.49 ±15.09	3.27 ±2.10	71.37 ±11.79	28.59 ±11.78	33.94 ±17.59	74.14 ±24.47
Scenario 3	61.15 ± 9.78	110.69 ±15.21	78.92 ±11.85	50.78 ±25.45	24.16 ±35.97	3.46 ±2.09	72.79 ± 11.35	27.42 ±11.52	36.58 ±17.99	79.22 ±26.44
Scenario 4	60.55 ± 9.35	111.97 ±22.15	77.40 ±11.78	50.87 ±25.70	22.18 ±15.54	2.99 ±1.92	70.11 ±11.62	29.80 ±11.60	35.89 ±18.23	77.44 ±27.86
Scenario 5	62.14 ± 9.01	120.58 ±42.32	82.64 ±12.62	48.57 ±22.24	19.95 ±13.11	3.29 ±2.13	71.57 ±11.85	28.35 ±11.84	34.34 ±15.75	77.77 ±23.52
Scenario 6	63.05 ± 9.68	114.31 ±18.70	82.28 ±12.91	49.13 ±24.74	21.02 ±15.92	3.04 ±1.88	70.74 ±11.23	29.45 ± 11.33	34.80 ±17.48	76.62 ±24.13
Scenario 7	62.50 ± 9.44	112.54 ±14.49	81.40 ±12.86	47.29 ±22.30	20.62 ±14.35	3.34 ±1.83	73.45 ±9.32	27.17 ±10.69	33.43 ±15.80	79.22 ±41.78
Scenario 8	60.81 ± 9.80	111.54 ±18.06	79.04 ±12.18	55.24 ±34.08	22.19 ±14.97	4.27 ±7.77	71.49 ±13.75	27.21 ±11.42	38.08 ±19.88	82.68 ±28.80
Scenario 9	62.68 ± 9.33	114.75 ±19.66	82.12 ±13.78	47.03 ±24.39	19.27 ±14.38	3.29 ±1.78	72.68 ±10.30	27.07 ±10.19	33.91 ±18.35	72.24 ±23.98
Scenario 10	63.32 ± 9.20	119.34 ±25.73	82.03 ±12.51	49.22 ± 25.75	20.34 ±15.04	3.27 ±1.97	71.93 ±11.30	28.09 ±11.46	34.72 ±18.25	77.66 ±27.21
Scenario 11	64.48 ± 10.44	115.14 ±22.20	83.61 ±13.98	46.05 ±24.48	18.87 ±14.57	3.40 ±2.07	71.31 ±12.60	28.64 ±12.58	32.39 ±17.60	74.48 ±26.49
Scenario 12	63.98 ± 9.74	114.51 ±16.38	84.59 ±13.67	47.54 ±24.72	18.79 ±13.43	3.66 ±2.50	72.94 ±11.96	27.03 ±11.94	33.63 ±17.49	76.97 ±26.81
***F*-value**	2	1.71	3.03	.963	.898	1.066	.640	.608	.827	.779
***p*-value**	.017	.065	.001	.478	.542	.386	.795	.823	.613	.662
η^2p	.189	.051	.196	.025	.024	.020	.022	.019	.022	.019
Post Hoc	S1 > S4 $p < .001$		S1 > S3 $p < .04$ S1 > S4 $p < .01$ S4 < S12 $p < .01$							

Note: HRmin: minimum heart rate; HRmax: maximun heart rate; HRmed: mean heart rate; RMSSD: the square root of the average of the sum of the differences squared between normal adjacent R-R; PNN50: the percentage of differences between normal adjacent R-R intervals greater than 50 ms; LF/HF: the ratio between low and high frequency band; LF: the low-frequency band in normalized units; HF: the high-frequency band in normalized units; SD1: the sensitivity of the short-term variability; SD2: the sensitivity of the long-term variability.

.

DISCUSSION

The purpose of this study was to analyse the autonomic stress response of last year's Exercise and Sport Sciences students during the 12 scenarios of their OSCE. Our initial hypothesis was confirmed; students' stress response was high during their OSCE. However, the second hypothesis was not fulfilled since the students' sympathetic and parasympathetic responses did not significantly change across the OSCE scenarios.

Data reported showed that the Exercise and Sport Sciences Degree OSCE was a stressful event for students. The HRV results indicated that the autonomic stress response of the students was high in the time domain, frequency domain, and nonlinear spectrum variables. This led to an increase in sympathetic modulation and low parasympathetic modulation of the nervous system due to the uncertain and uncontrollable characteristics of an OSCE. Students perceived the OSCE as a threatening event where they were observed and their competencies assessed. The OSCE was part of the evaluation of a course called Practicum in which student completed a stay in a professional setting (e.g. high school, fitness center, or coaching staff) where they demonstrated their competencies and skills. Additionally, this was the first time students faced an OSCE. To our knowledge, it was also the first time an OSCE was used to evaluate Exercise and Sport Sciences students. Therefore, this academic event was undoubtedly a significant stressor for the student. Similar stress responses have been observed by our research group in physiotherapy (Martinez-Pascual et al., 2022), psychology (Beltran-Velasco et al., 2018), and nursing OSCE (Conde & Clemente-Suarez, 2021). Other educational contexts have also been shown to be stressful environments that trigger high stress responses, such as clinical placements (Beltran-Velasco et al., 2019), final degree dissertation (Ramirez-Adrados et al., 2020), and practical exams (Sanchez-Conde et al., 2022).

Regarding the central nervous system modulation during the OSCE, data showed a maintained response of the sympathetic modulation in all the scenarios. This maintained anxiogenic response could be explained because it was the first time the students participated in this type of methodological evaluation, which was a novel, uncontrollable, and unpredictable environment for them. As we have highlighted, to our knowledge, this was the first OSCE performed in the Exercise and Sport Sciences degree. In this line, compared to other OSCEs performed in other degrees, our students faced a higher number of stations (Bobos et al., 2021), and this fact could lead our students to a large anxiogenic response. A similar OSCE structure was carried out in a physiotherapy OSCE analysed by our group (Martinez-Pascual et al., 2022). Both groups of students exhibited similar sympathetic modulation during their respective OSCEs. However, Exercise and Sport Science students'

HRV data showed slightly more favourable results regarding stress and anxiogenic responses, with higher HRV values. We could argue that Exercise and Sport Sciences students presumably have a better physical activity profile, and thus, they could better assume the stress (Redondo-Florez et al., 2022). However, and we state this fact as a limitation, we did not evaluate the physical activity profile to ensure this.

Contrary to our second hypothesis, HRV data showed that the autonomic modulation of the students was similar in all the OSCE scenarios, despite there were two rest stations and two written scenarios. This means that the stress generated by facing the OSCE was so superior that the differences in difficulty and emotional impact of the scenarios had no effect. In this regard, it is important to highlight that the sequence of scenarios is different for each student since they were randomly assigned to the scenario where each one began the OSCE, and all of them rotated in ascending order. Also, this design avoided a possible habituation response along the OSCE would occur in the same scenarios., We expected that the scenarios with higher emotional load and difficulty (i.e., S1 and S9) would elicit a greater stress response. Surprisingly, these scenarios reported similar HRV values to the other scenarios. This difference in difficulty and stress perception between students and educators facing an OSCE has already been studied in previous research (Conde & Clemente-Suarez, 2021). Regarding the scenarios, HRV data did not show significant differences between them, but the cardiac response did have significant differences. S1 (conflict management in team sport) provoked a higher HRmin and HRmean than S4 (physical education class design) and a higher HRmean than S3 (rest). Also, S12 (physical condition assessment) had a greater HRmean response than S4. S1 and S12 shared the commonality that students encountered simulated athletes (actors) in contexts related to the content of the sport sciences profession, where reasoning and decision-making skills are crucial. Besides, S4 was a written scenario, and thus, its demands were akin to a written test, an evaluation process that students had commonly performed throughout their academic life since basic school. The fact that the students were in the rest station (S3) and right after faced the S4, where they did not interact with individuals, could explain this reduction in the heart rate response.

The analysis of HRV to evaluate the autonomic stress response is an innovative method to determine how stressful situations affect related abilities, performance, and skills across various fields such as exercise training, sport, military, health, and academics (Fernandez-Elias et al., 2022; Ramirez-Adrados et al., 2020; Redondo-Florez et al., 2022; Tornero-Aguilera et al., 2020; Tornero-Aguilera et al., 2021). Thus, this tool has demonstrated its sensitivity in order to identify the magnitude of the autonomic response in very different contexts and situations. However, HRV parameter sensitivity seems different depending on what kind of stress is evalu-

ated. In this line, time domain variables have previously been shown to be more sensitive when analysing stress in an academic context (Beltran-Velasco et al., 2019; Martinez-Pascual et al., 2022). Therefore, the data reported in this study are in concordance with these previous reports, since heart rate values belong to this HRV spectrum. Nevertheless, more research is needed in order to fully understand the possibilities of HRV to measure stress in different contexts and populations.

The results of this study provide useful information for improving OSCE design and implementation in Exercise and Sport Sciences. Firstly, the persistent sympathetic activation observed across all scenarios suggests that the current format of the OSCE generates a sustained stress response, regardless of the specific scenario. Therefore, educators and course designers could consider gradually introducing OSCE-like situations throughout the academic curriculum, helping students become familiar with this type of evaluation and reducing its novelty and uncertainty.

Secondly, the use of HRV as a monitoring tool offers the opportunity to evaluate student stress in real time and adapt the structure or sequence of scenarios accordingly, for example, by strategically placing rest or lower-demand stations after high-pressure scenarios. In this sense, autonomic modulation data may serve not only as a research variable but also as a practical feedback tool to improve students' experience and performance.

Lastly, understanding the autonomic stress profile of students during OSCEs could help design targeted interventions (e.g., mental preparation strategies, breathing, or relaxation techniques) to reduce stress levels and enhance performance during high-stakes assessments.

CONCLUSIONS

Summarizing, the findings of the present study were that Exercise and Sport Science degree students had a large stress response and a maintained sympathetic autonomic modulation during the OSCE. To the best of our knowledge, this was the first time that Exercise and Sport Science degree students undertook an OSCE as a competency evaluation method, which could explain the similar HRV response in all the scenarios, despite the varying content and context, as well as in the break stations. Therefore, an OSCE is an evaluation methodology that can be implemented in Exercise and Sport Sciences degrees to assess students' competencies and practical skills. Besides, monitoring the autonomic modulation of students allows teachers to design OSCE scenarios more adapted to the students, restraining the effect of the stress response to allow a better performance. On the other hand, this study is not without limitations. The measurement of stress hormones (i.e. cortisol and alpha amylase) could have provided more information about the students' stress

response. Also, there were unmeasured individual traits like prior OSCE experience or psychological resilience.

ACKNOWLEDGEMENTS

The results of this study do not constitute an endorsement of any product by the authors and have no conflicts of interest relevant to the project to disclose.

FUNDING

This research was funded by a grant from the Universidad Europea de Madrid, ref: 2022/UEM06.

REFERENCES

Bagheri, M., Sadeghnezhd Forotgheh, M., & Shaghayee Fallah, M. (2012). The comparison of stressors in the assessment of basic clinical skills with traditional method and OSCE in nursing students. *Life Science Journal, 9*(4), 1748-1752. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=4438924bfca121d88fb75d6ee33950bb9cd0f75e#:~:text=Most%20of%20the%20students%20considered%20OSCE%20more%20accurate%20than%20traditional,station%20of%20OSCE%20were%20examined

Beltran-Velasco, A. I., Bellido-Esteban, A., Ruisoto-Palomera, P., & Clemente-Suarez, V. J. (2018). Use of portable digital devices to analyze autonomic stress response in psychology objective structured clinical examination. *Journal of Medical Systems, 42*(2), 35. https://doi.org/10.1007/s10916-018-0893-x

Beltran-Velasco, A. I., Ruisoto-Palomera, P., Bellido-Esteban, A., Garcia-Mateos, M., & Clemente--Suarez, V. J. (2019). Analysis of psychophysiological stress response in higher education students undergoing clinical practice evaluation. *Journal of Medical Systems, 43*(3), 68. https://doi.org/10.1007/s10916-019-1187-7

Beltran-Velasco, A. I., Mendoza-Castejon, D., Fuentes-Garcia, J. P., & Clemente-Suarez, V. J. (2020). Behavioural, psychological, and physiological stress markers and academic performance in immigrant and non-immigrant preschool and school students. *Physiology & Behavior, 225*, 113081. https://doi.org/10.1016/j.physbeh.2020.113081

Bellido-Esteban, A., Beltran-Velasco, A. I., Ruisoto-Palomera, P., Nikolaidis, P. T., Knechtle, B., & Clemente-Suarez, V. J. (2021). The Effect of psychology objective structured clinical examination scenarios presentation order on students autonomic stress response. *Frontiers in Psychology, 12*, 622102. https://doi.org/10.3389/fpsyg.2021.622102

Bobos, P., Pouliopoulou, D. V., Harriss, A., Sadi, J., Rushton, A., & MacDermid, J. C. (2021). A systematic review and meta-analysis of measurement properties of objective structured clinical examinations used in physical therapy licensure and a structured review of licensure practices in countries with well-developed regulation systems. *PLoS One, 16*(8), e0255696. https://doi.org/10.1371/journal.pone.0255696

Bogo, M., Regehr, C., Logie, C., Katz, E., Mylopoulos, M., & Regher, G. (2011). Adapting objective structured clinical examinations to assess social work students' performance and reflections. *Journal of Social Work Education, 47*(1), 5-18. https://doi.org/10.5175/JSWE.2011.200900036

Cano García, E. (2008). La evaluación por competencias en la educación superior: el papel de los profesores universitarios. Profesorado. *Revista de Currículum y Formación del Profesorado, 12*(3), 1–16. https://revistaseug.ugr.es/index.php/profesorado/article/view/20503

Carraccio, C., & Englander, R. (2000). The objective structured clinical examination: a step in the direction of competency-based evaluation. *Archives of Pediatrics & Adolescent Medicine, 154*(7), 736-741. https://doi.org/10.1001/archpedi.154.7.736

Clemente-Suarez, V. J., & Robles-Perez, J. J. (2013). Mechanical, physical, and physiological analysis of symmetrical and asymmetrical combat. *Journal of Strength and Conditioning Research, 27*(9), 2420-2426. https://doi.org/10.1519/JSC.0b013e31828055e9

Conde, P. S., & Clemente-Suarez, V. J. (2021). Differences between students and professors in difficulty, stress and performance in a nursing Objective Structured Clinical Examination (OSCE). *Physiology & Behavior, 239*, 113502. https://doi.org/10.1016/j.physbeh.2021.113502

Delgado-Moreno, R., Robles-Pérez, J. J., & Clemente-Suárez, V. J. (2017). Combat stress decreases memory of warfighters in action. *Journal of Medical Systems, 41*(124). https://doi.org/10.1007/s10916-017-0772-x

Delgado-Moreno, R., Robles-Pérez, J. J., Aznar-Laín, S., & Clemente-Suárez, V. J. (2019). Effect of experience and psychophysiological modification by combat stress in soldier's memory. *Journal of Medical Systems, 43*(150). https://doi.org/10.1007/s10916-019-1261-1

Espejo-Antunez, L., Fernandez-Morales, C., Hernandez-Sanchez, S., Cardero-Duran, M. L. A., Toledo--Marhuenda, J. V., & Albornoz-Cabello, M. (2022). The Impact on the stress-associated autonomic response of physiotherapy students receiving interferential current in an electrotherapy training session. *International Journal of Environmental Research and Public Health, 19*(20), 13348. https://doi.org/10.3390/ijerph192013348

Fernandez-Elias, V. E., Tobia, D., Recarey, A., Fernandez, A., Clemente-Suarez, V. J., & Burgos-Postigo, S. (2022). Acute effects of whole-body electromyostimulation during a single maximal strength training session. *International Journal of Environmental Research and Public Health, 19*(21), 13753. https://doi.org/10.3390/ijerph192113753

Giles, D., Draper, N., & Neil, W. (2016). Validity of the Polar V800 heart rate monitor to measure RR intervals at rest. *European Journal of Applied Physiology, 116*(3), 563-571. https://doi.org/10.1007/s00421-015-3303-9

Harden, R. M., Stevenson, M., Downie, W. W., & Wilson, G. M. (1975). Assessment of clinical competence using objective structured examination. *British Medical Journal, 1*(5955), 447-451. https://doi.org/10.1136/bmj.1.5955.447

Hood, A., Pulvers, K., Spady, T. J., Kliebenstein, A., & Bachand, J. (2015). Anxiety mediates the effect of acute stress on working memory performance when cortisol levels are high: a moderated mediation analysis. *Anxiety, Stress and Coping, 28*(5), 545-562. https://doi.org/10.1080/10615806.2014.1000880

Khan, K. Z., Ramachandran, S., Gaunt, K., & Pushkar, P. (2013). The Objective Structured Clinical Examination (OSCE): AMEE Guide No. 81. Part I: an historical and theoretical perspective. *Medical Teacher, 35*(9), e1437-1446. https://doi.org/10.3109/0142159X.2013.818634

Martinez-Pascual, B., Ramirez-Adrados, A., Fernandez-Martinez, S., Gonzalez-de-Ramos, C., Fernandez-Elias, V. E., & Clemente-Suarez, V. J. (2022). Autonomic stress response of physiotherapy

student in the different scenarios of an objective structured clinical examination. *BMC Medical Education, 22*(1), 811. https://doi.org/10.1186/s12909-022-03903-9

Mendoza-Castejon, D., & Clemente-Suarez, V. J. (2020). Psychophysiological stress markers and behavioural differences between rural and city primary school students. *International Journal of Environmental Research and Public Health, 17*(9). https://doi.org/10.3390/ijerph17093157

Miller, G. E. (1990). The assessment of clinical skills/competence/performance. *Academic Medicine, 65*(9 Suppl), S63-67. https://doi.org/10.1097/00001888-199009000-00045

Morgan, C. A., Doran, A., Steffian, G., Hazlett, G., & Southwick, S. M. (2006). Stress-induced deficits in working memory and visuo-constructive abilities in Special Operations soldiers. *Biological Psychiatry, 60*(7), 722-729. https://doi.org/10.1016/j.biopsych.2006.04.021

Newble, D. (2004). Techniques for measuring clinical competence: objective structured clinical examinations. *Medical Education, 38*(2), 199-203. https://doi.org/10.1111/j.1365-2923.2004.01755.x

Ramirez-Adrados, A., Fernandez-Martinez, S., Martinez-Pascual, B., Gonzalez-de-Ramos, C., Fernandez-Elias, V. E., & Clemente-Suarez, V. J. (2020). Psychophysiological stress response of physiotherapy last year students in his final degree dissertation. *Physiology & Behavior, 222*, 112928. https://doi.org/10.1016/j.physbeh.2020.112928

Redondo-Florez, L., Ramos-Campo, D. J., & Clemente-Suarez, V. J. (2022). Relationship between physical fitness and academic performance in university students. *International Journal of Environmental Research and Public Health, 19*(22). https://doi.org/10.3390/ijerph192214750

Sanchez-Conde, P., Beltran-Velasco, A. I., & Clemente-Suarez, V. J. (2022). Analysis of the objective and subjective stress response of students and professors in practical nursing exams and their relationship with academic performance. *International Journal of Environmental Research and Public Health, 19*(15). https://doi.org/10.3390/ijerph19159121

Sloan, D. A., Donnelly, M. B., Schwartz, R. W., & Strodel, W. E. (1995). The Objective Structured Clinical Examination. The new gold standard for evaluating postgraduate clinical performance. *Annals of Surgery, 222*(6), 735-742. https://doi.org/10.1097/00000658-199512000-00007

Starcke, K., Wiesen, C., Trotzke, P., & Brand, M. (2016). Effects of Acute Laboratory Stress on Executive Functions. *Frontiers in Psychology, 7*, 461. https://doi.org/10.3389/fpsyg.2016.00461

Tornero-Aguilera, J. F., & Clemente-Suarez, V. J. (2018). Effect of experience, equipment and fire actions in psychophysiological response and memory of soldiers in actual underground operations. *International Journal of Psychophysiology, 128*, 40-46. https://doi.org/10.1016/j.ijpsycho.2018.03.009

Tornero-Aguilera, J. F., Sanchez-Molina, J., Fernandez-Elias, V. E., & Clemente-Suarez, V. J. (2020). Psychophysiological stress response of novice cavers in a speleology route. *Wilderness & Environmental Medicine, 31*(3), 259-265. https://doi.org/10.1016/j.wem.2020.02.001

Tornero Aguilera, J. F., Fernandez Elias, V., & Clemente-Suarez, V. J. (2021). Autonomic and cortical response of soldiers in different combat scenarios. *BMJ Military Health, 167*(3), 172-176. https://doi.org/10.1136/jramc-2019-001285