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Physiological and psychological responses of surgeons and trainees

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Abstract

Performing surgical procedures can increase the physiological stress and mental strain experienced by practicing surgeons and their trainees. This may negatively affect work and learning capacity and quality of patient care by increasing the incidence of burnout, sleep disorders, fatigue and other negative behaviours such as substance abuse. This study aimed to compare the physiological and psychological responses of similar clinical situations between orthopaedic surgeons and their clinical fellows. An observational prospective cohort study was performed in that matter. Our results showed overall increased physiological responses of the fellows during surgery days compared to the clinic days. On the contrary, staff did not show significant variability in their physiological responses between OR and clinic days. Type of procedure and type of approach used for a procedure had a distinct effect on fellows' physiological responses. Further evaluation including physiological responses during different intraoperative steps might help identify specific stressors present in the working and learning environment.

Keywords

Stress; Heart Rate; Surgical training; HRV; Remote Monitoring

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List of Abbreviations

%HRmax – Percentage of maximal effort

ACh – Acetylcholine

ACTH – Adrenocorticotropic hormone

ANOVA – Analysis of variance

ANS – Autonomic nervous system

ATP – Adenosine Triphosphate

BMI – Body-mass index

bpm – Beats per minute

CNS – Central nervous system

CRH – Corticotropin-releasing hormone

EKG – Electrocardiogram

FSH – Follicle-stimulating hormone

HF – High frequency

HPAA – Hypothalamic-pituitary-adrenal axis

HR – Heart rate

HRV – Heart rate variability

LF – Low frequency

LH – Luteinizing hormone

MAO – Monoamine oxidase

NE - Norepinephrine

NTS – Nucleaus of the solitary tract

OR – Operating room

PNS – Parasympathetic nervous system

pTHA – Primary total hip arthroplasty

pTKA – Primary total knee arthroplasty

REB – Research Ethics Board

rTHA – Revision total hip arthroplasty

rTKA – Revision total knee arthroplasty

SD – Standard deviation

SNS – Sympathetic nervous system

STAI – State-trait Anxiety questionnaire

THA – Total hip arthroplasty

TKA – Total knee arthroplasty

TSH – Thyroid-stimulating hormone

UK – United Kingdom

US – United States of America

VIP – Vasoactive intestinal peptide

Chapter 1

1 Introduction

Surgical education has undergone significant changes over the last number of years. An increased understanding of how work conditions effect surgical trainees has led to significant changes for many surgical training programs. As a self-regulating profession, physicians have organizational licensure standards, and therefore surgical education is critically important to the Royal College of Physicians and Surgeons. As shown in a recent meta-analysis, numerous studies demonstrate that the current learning environment is suboptimal and trainees are exposed to high levels of stress[17]. Therefore, there is an ongoing need to make changes in medical and surgical training. Promotion of competency-based type training is being increasingly utilized to intentionally understand the unique needs of each resident, and to evaluate specific steps in the trainee's development. However, we lack information on which elements in the environment have a more substantive effect on the stress level experienced by the trainees. Most of the information present in the current literature is based on psychological questionnaires and are focused on medical training. The primary goal of this study was to track the physiological responses of surgeons and their trainees during their clinical duties and to correlate those responses with psychological responses. The following chapter outlines the considerations leading to the development of this project.

1.1 Definition of stress

Stress is the sum of biological responses of an organism to any real or perceived challenge to which it is exposed[27]. These responses can be on different levels including molecular, physiological, cognitive and/or behavioral. The autonomic nervous system (ANS) in conjunction with the hypothalamic-pituitary-adrenal axis (HPAA) are the main systems responsible for the control of these responses[36]. The goal of these responses is to allow the organism to maintain a physiological homeostasis despite changes within the internal and/or external environment[36].

1.2 Autonomic nervous system: Physiology and response to stress

The ANS is the part of the nervous system that is responsible for the innervation of the tissues other than the skeletal system. It has three different divisions: the sympathetic nervous system (SNS), the parasympathetic nervous system (PNS) and the enteral nervous system. The latter is sometimes considered a distinct part of the nervous system itself and its description is beyond the scope of this project. The main role of this ANS is to help maintaining homeostasis in the body despite its exposure to varying conditions[36].

Centrally, the control of the ANS is the responsibility of a network of interconnected structures. In the forebrain, the major structures involved are the hypothalamus, the limbic system and especially the amygdala and the prefrontal cortex. In the brainstem, a multitude of nuclei, including the nucleus of the solitary tract (NTS), participate in the control of the ANS[24].

Sensory information from the different tissues arrive through afferent nerves to the NTS where information is processed and transmitted within the extensive central network of the ANS. Once this information is processed and relayed to the hypothalamus, the information indirectly obtained is combined with the data collected from the hypothalamic internal thermoreceptors and chemoreceptors measuring the local changes in temperature and chemical composition of the blood. This permits the hypothalamus to regulate different basic physiological processes and needs, including body temperature, metabolic, reproduction, baseline blood pressure and electrolyte homeostasis and the response to emergency functions, including reactions to stress[24].

The control of those physiological needs is performed through two different methods. First, a hormonal control is performed through the hypothalamic-pituitary axis. Second, an efferent signal is transmitted to the different tissues through the sympathetic and parasympathetic nervous systems[36].

The ANS has anatomic and physiological differences to the efferent somatic nervous system. Although the nerves innervating the skeletal muscles consists of a single neuron leaving the CNS and reaching the muscle fibers, the ANS efferent system consists of a two-neuron chain connected by a synapse between CNS and effector tissue. Moreover, although innervation from the somatic nervous system is only tonical, the effect of the innervation from the ANS can be either inhibitory or excitatory[36].

The different divisions of the ANS also have anatomic and physiological differences between themselves. As noted above, the efferent innervation consists of a two-neuron chain between CNS and efferent tissue. In the SNS, ganglia lie near the spinal cord forming two chains on either side of the spinal cord called sympathetic chains. Preganglionic fibers leave the CNS from the first thoracic to the rostral lumbar segments of the spinal cord to reach the sympathetic chain where they create synapses with the postganglionic fibers. In contrast, the PNS preganglionic fibers exit the CNS from multiple cranial nerves and the sacral segments of the spinal cord to reach ganglia that lie within or nearby the efferent organs[24] (Fig 1-1).

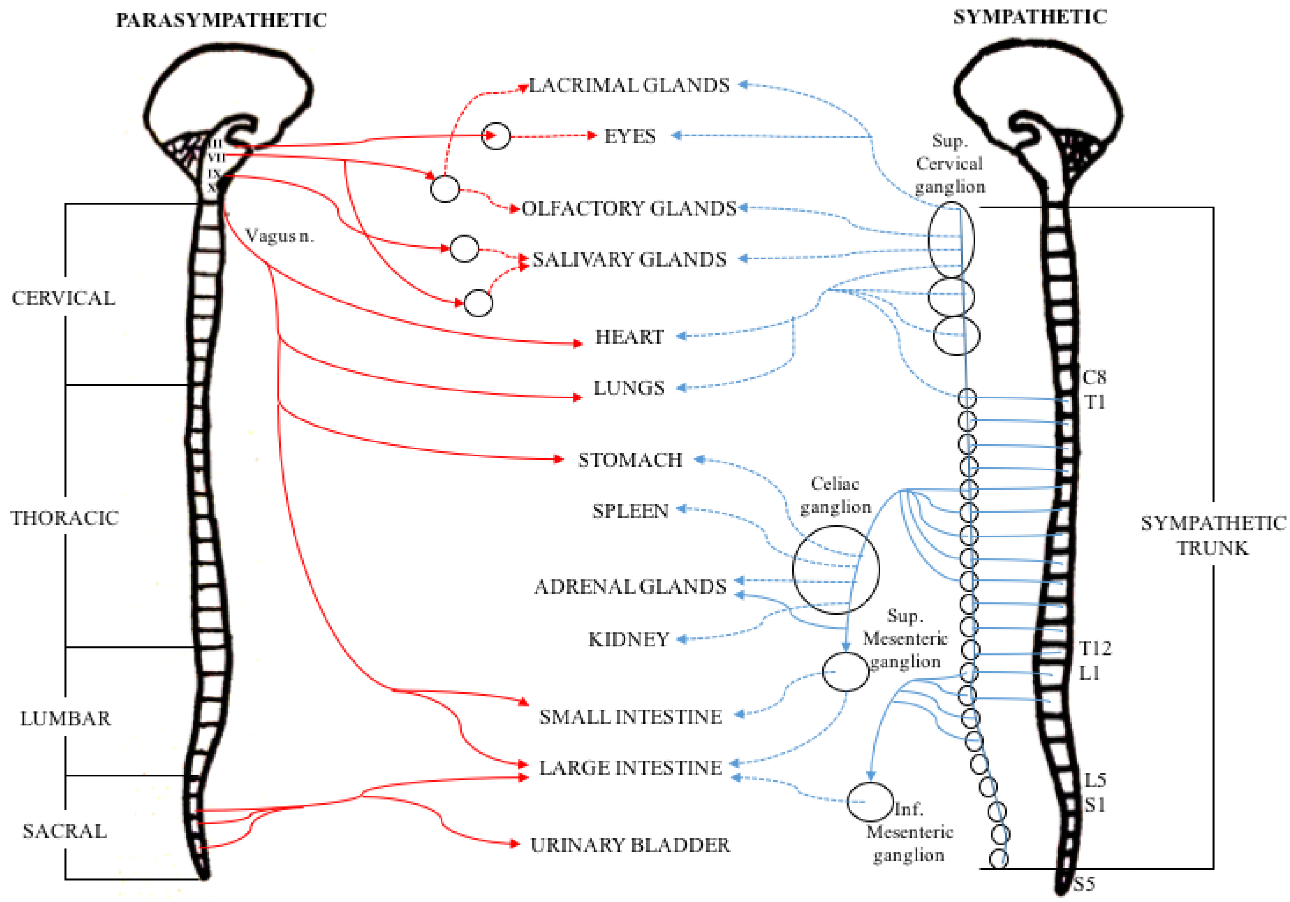


Figure 1-1 Sympathetic (Red) and Parasympathetic (Blue) nervous system (Sup. – Superior, Inf. – Inferior) (S. Abatzoglou)

Another major difference between ANS and the somatic nervous system is that the postsynaptic regions are not specialized in the ANS. This permits a more diffuse, less specific control of the cell within a tissue through diffusion of the neurotransmitters within the interstitial fluid[24].

Major neurotransmitters involved in the ANS are acetylcholine (ACh) and norepinephrine (NE). ACh is mainly released by all the preganglionic fibers of the ANS, regardless of the division, as well as by the postganglionic fibers of the PNS. In all synapses, ACh is mainly inactivated by acetylcholinesterase in a very fast fashion requiring less than 1ms to clear the synapse[24].

NE is mainly released by the postganglionic fibers of the SNS to the target tissues. Clearance of NE from the synaptic cleft is more time consuming than ACh clearance, thus leading to a slower return to prestimulation level from SNS compared to PNS stimulation[24].

The adrenal medulla cells are postganglionic sympathetic cells that did not develop into nerve cells and their role is to release catecholamines into the bloodstream to permit more systemic effect of the SNS to the various organs throughout the body. Catecholamines in the bloodstream are typically metabolized in the liver[24].

Other neurotransmitters or co-transmitters having a certain role in the ANS are epinephrine, ATP, adenosine, vasoactive intestinal peptide (VIP), neuropeptide Y, enkephalins, neurotensin, somatostatin and substance P, however their study is beyond the scope of this project[36].

The classic model to describe the physiology of the ANS is a model where the different divisions are active sequentially depending on whether the individual is in a rest situation or an active stressful situation. However, a different model has been described lately where both the SNS and PNS are functioning continuously in different intensities and it is the balance between them that dictates the arousal level of an individual and the response noted to environmental changes[15].

1.3 Oscillation of ANS and Heart rate variability

Rapid behavioral adjustments are regulated in the sympathetic nervous system mainly by structures within the cortex as well as within the limbic system and the midbrain. Nevertheless, the basal sympathetic tone is set by multiple structures within the central nervous system. Oscillations of the basal sympathetic tone have been noted to be present at any given time. When those oscillations are recorded, two main types of rhythms are distinguished: oscillations with lower frequency ranging from 2 Hz to 6 Hz and oscillations with higher frequency at or greater than 10 Hz[20].

Lower frequency oscillations seem to correlate better with the cardiac cycle. Both SNS and PNS have an effect in producing these types of oscillations and they have been related to the cardiac cycle. On the contrary, higher frequency oscillations seems to be affected by respiratory rate. In contrast to lower frequency oscillations, the high frequency oscillations are mainly affected by the action from the PNS and they represent a marker of the baseline activity of the ANS. In general, heart rate variations are a reflection of the presence of the lower frequency oscillations[31].

The concept of heart rate variability is based on the observation of the variation of the heart rate of an individual[20]. It can be measured in a beat-to-beat fashion or in a time period. On an EKG recording corresponding to a certain period, the interval between each R-wave on the recording is noted. These data helps establish low frequency and high frequency periods after calculation through one of the numerous technique available (calculation techniques beyond the scope of this thesis) HRV is then obtained by calculating the ratio between the low frequency (LF) and high frequency (HF) oscillations described above[20]. Since the low frequency oscillations are primarily present during activation of the sympathetic nervous system from a stressful stimulus, the ratio tends to increase as the sympathetic activation is increased. Due to its characteristics, HRV has been demonstrated in previous studies to be one of the most reliable markers of autonomic responses[30].

Researchers attempted to identify reference values for heart rate variability during resting moments to permit a better understanding of the variations noted[1]. However, such values are difficult to establish since heart rate variability is affected by multiple factors including age, gender and fitness level of individuals[2,32].

1.4 Hypothalamic-pituitary axis (HPA): Physiology and response to stress

The second pathway involved in the stress response in order to maintain the body homeostasis involves the hypothalamic-pituitary axis (HPA). Similar to the autonomic nervous system, the hypothalamus represents the central regulatory structure of the nervous system receiving and integrating all the afferent data and regulating the response to external stressors to maintain homeostasis. However, in addition to its autonomic function, it also has an endocrine function[36].

The hypothalamus is closely interconnected with the pituitary gland through a stalk containing both nerve fibers as well as a blood vessel and capillary system allowing communication between the two structures. They are situated near the base of the skull within a structure called the sella turcica[36].

The pituitary gland itself is made of two lobes. First, the anterior lobe containing endocrine cells receiving endocrine signaling from the hypothalamic-pituitary portal system. The anterior lobe is then responsible for the release of hormones, including growth hormone, thyroid stimulating hormone, follicle-stimulating and luteinizing hormones, prolactin, as well as adrenocorticotropic hormone (ACTH). Second, the posterior lobe is made of the extension of nerve fibers originating from the hypothalamus that release the hormones vasopressin and oxytocin directly into the bloodstream[36] (Fig 1-2).

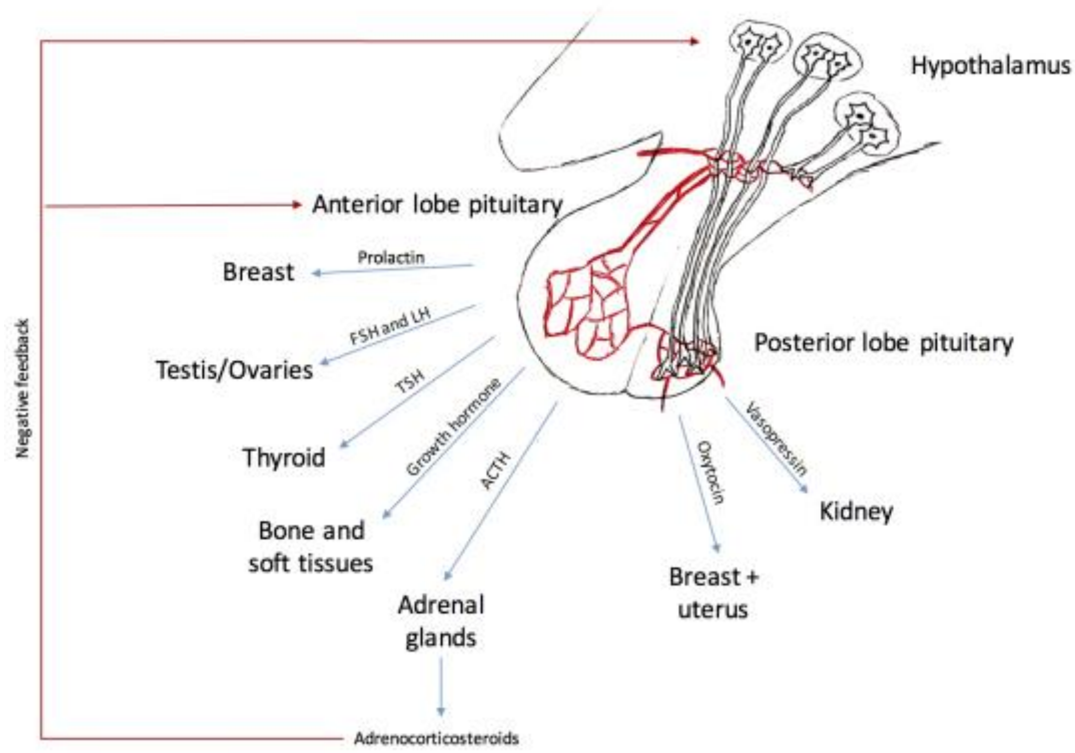


Figure 1-2 Hypothalamic-pituitary-adrenal axis (FSH – Follicle-stimulating hormone, LH – Luteinizing hormone, TSH – Thyroid-stimulating hormone, ACTH – Adrenocorticotropic hormone)

During a stress response, the hypothalamus receives inputs from the different areas of the central nervous system as well as from direct receptors, and releases fluctuating levels of corticotropin-releasing hormone (CRH) within the hypothalamic-pituitary portal system. CRH simulates the anterior pituitary to release ACTH into the bloodstream. ACTH stimulates the adrenal gland to produce and release multiple adrenocorticosteroids in the bloodstream including cortisol. Multiple organs are the targets of cortisol and react to its increased level by mounting a response that helps to maintain the internal homeostasis combating the stressor affecting the body. It also permits a better reactivity to the hormones, epinephrine and norepinephrine, enhancing this response to stress[36].

A baseline level of cortisol is always present within the bloodstream. Oscillations in the serum level of cortisol are present in a circadian rhythm fashion[6]. However, those variations are slower, and only a total increase in cortisol release during a period of time can be noted as a marker of a stress response.

1.5 Cognitive response to stress

In 1979, Nixon demonstrated the relationship between the amount of the stress response and performance[22] (Fig. 1-3). According to his analysis, as the arousal stress increases, the performance is positively affected. However, once the amount of stress experienced was greater than the amount an individual could handle, that individual had reached the fatigue point and the performance was actually negatively affected. Learning and stress management strategies affect this relationship in two different ways. First, they allow an individual to reach a higher level of performance for a certain amount of stress experienced. Second, they allow each individual to push their fatigue point to a higher arousal stress level, therefore leading once more to performance optimization.

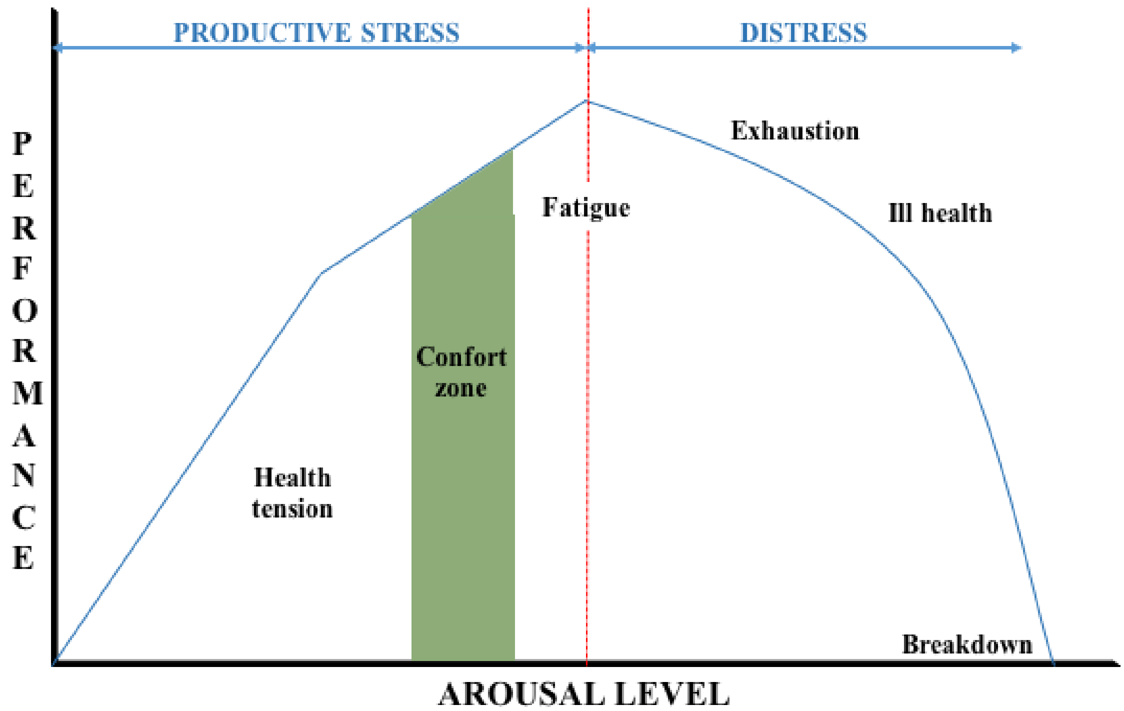


Figure 1-3 Human function curve (Adapted from: Nixon P: Practitioner 1979)

Stress has similar effects to learning and memory re-creation. Yerkes and Dodson were the first to describe that relationship (Fig. 1-4). According to this concept, for simple task acquisition not requiring particular thought processes or without multitasking, there is a positive effect of arousal level and learning abilities up to a maximal learning capacity of an individual. However, for more complex working memory requiring multitasking and decision-making, learning abilities exhibit a similar response to stress and performance. An inverted-U shaped relationship between arousal stress level and efficiency of memory acquisition[38]. There is no clear etiology established to explain this correlation at this point, although some theories exist. For instance, a recent study found similar correlations between cortisol dose given to individuals and the capacity for memory retrieval[26], therefore suggesting that cortisol might play a role in this process. Also, psychologists working on learning disabilities in young children explain that when stress levels become overwhelming, the body concentrates more on its survival rather than learning new complex abilities.

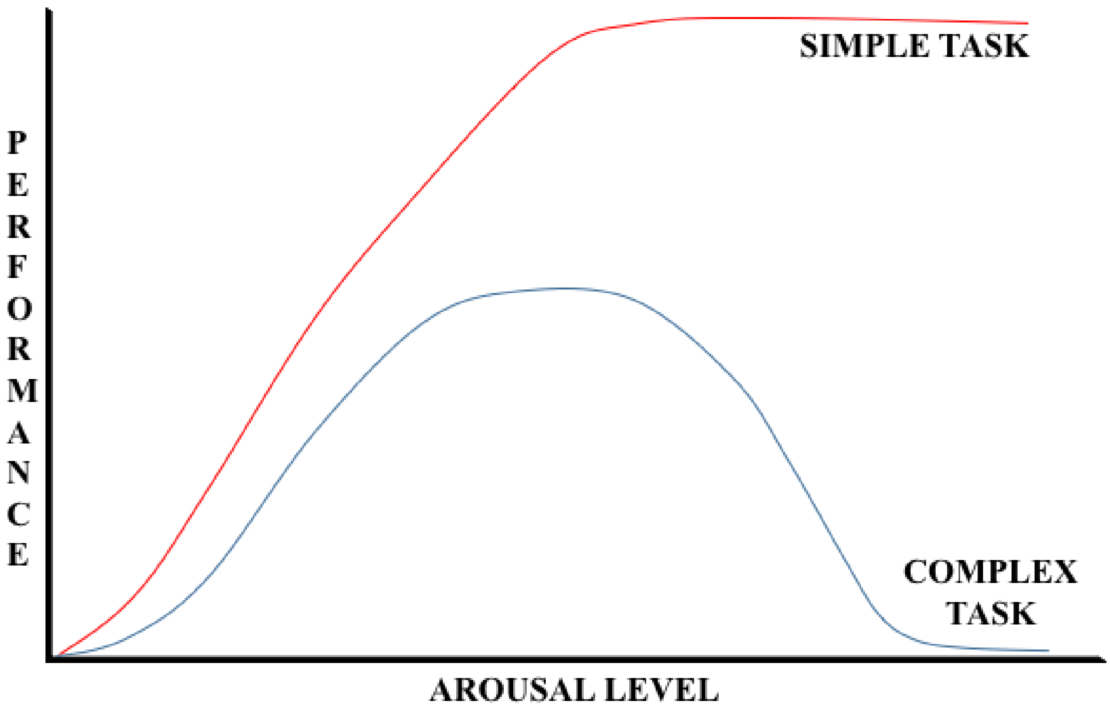


Figure 1-4 Yerkes-Dodson law (S. Abatzoglou)

1.6 Stress in the medical field

Surgeons, as well as the surgical team working with them, are exposed to high levels of stress. A study published in 2009 showed a burnout rate of 40% among American surgeons[28]. Another study from China showed even higher levels of burnout up to 60.6% of physicians across 21 different hospitals[32]. High levels of stress do not only lead to increased levels of burnout, but also may negatively affect the efficiency, efficacy and surgeon's skill levels[4] and, therefore, may lead to deterioration of quality in patient care[35]. A Canadian questionnaire-study showed that among more than 3000 Canadian physicians, at least one in four physician showed periods of difficulty handling their workload, poor workload-life balance and evidence of depression within the evaluated year, with a majority being female[7].

Methods have been implemented and studied to deal with the increased stress noted in the healthcare workers. Mental practice use for surgeons just starting their practice has been studied in the United States. A prospective randomized controlled trial comparing surgeons using mental rehearsal of the procedure to surgeons not using this technique on a virtual reality simulator showed reduced objective stress parameters overall in the group using mental practice[4].

Other methods showing efficacy on healthcare workers in occupational stress reduction have been evaluated in a Cochrane meta-analysis review[25]. Physical relaxation methods showed moderate evidence compared to the no intervention cohorts on stress levels. Other methods such as cognitive-behavioral therapy, mental relaxation and work schedule interventions methods had low evidence to affect stress levels. Interventions such as support group organization, communication skill interventions and changes in work conditions did not show any evidence to alter workers' stress[25].

1.7 Stress and medical training

Similar to healthcare workers, medical trainees are exposed to high levels of stress. In addition to the time spent studying in order to acquire the proficiency required for their field, medical and surgical trainees have clinical duties that can involve high stress situations in a long work hours setting. This can be overwhelming for the trainees themselves, especially if they are working in a suboptimal setting in terms of a learning environment.

A recent meta-analysis published in December 2015 approached the question of the stress and depression amongst medical trainees[17]. A total of fifty-four studies, either cross-sectional or longitudinal type studies, from all across the world were included in that review with mainly questionnaire-based evaluations using different validated tools. The overall prevalence of depression in medical residents reached around 28.8% without significant differences between the type of studies, the country where the study was performed, or the medical specialty in which the residents were studying (surgical vs non-surgical). Gender did not show any effect on the prevalence of stress and depression[18].

Some studies attempt to identify the elements in the work environment that could lead to increased stress levels. Most of those studies were done in emergency medicine residents. A survey in residents within a large academic US hospital showed higher prevalence of burnout in residents with families compared to single residents due to the poor workload-life balance[12]. Also, there was a higher prevalence of burnout in residents with poor global job satisfaction. On the other hand, in another study involving mainly orthopaedic surgery residents, trainees with supportive significant others showed lower rates of distress and burnout[37]. A prospective cohort study of residents from another American academic institution showed that medical complications as well as anticipated overtime had a negative effect on trainees[37]. Poor diet can also lead to physical deterioration and increased stress level of the trainees. Studies have seen higher likelihood for obesity as the resident progress through their training[14] and results to increased stress. Sleep disturbances have also been found to have a significant effect on self-reported resident wellness[19].

As noted above, learning can be impeded by an overwhelming environment during medical training, where more complex decision-making activities are required. Therefore, it is crucial to investigate and understand the stresses inherent to current clinical duties and the response of trainees to these stresses. Changes have been already attempted to improve the work conditions of the trainees and optimize their learning experience. For instance, a mindfulness-based resilience intervention has been tested in Family Medicine, Psychiatry and Anesthesia training programs, which showed some positive effect of self-reported stress in female residents in junior years of training[10].

Other measures have been taken by some training programs to provide mental support to their residents. Unfortunately, only 28% of US residency programs included a complete stress management program for their trainee support, with most of the programs only providing only a single type of support measure[9]. Education on healthier lifestyle early in the medical training affected positively the rate of burnout in medical schools in the UK[5]. Another study showed that incentivized exercise programs lead residents and fellows to higher physical activity levels and higher quality of life[33].

Work hour regulations have also been introduced in recent years in medical training in certain jurisdictions[29]. When first introduced, the work hour restrictions attempted to improve quality of life by improving the workload-life balance. When first presented, the staff's opinion was not in favor of work hour restrictions, as they felt that there is not enough evidence that such measures lead to improved patient safety and improved environment for the residents[29]. Studies done in the years following the implementation of those restrictions have showed divergent results. Some studies support that they have not led to improvement in the self-reported experience of long working hours, fatigue and distress[21,23], while other studies showed improved quality of life[15]. In orthopaedic surgery residencies, different results were found. In a study from Toronto, the traditional work hour group of residents actually had better quality of life and similar educational experiences than the new work hour regulation resident group. On the contrary, another Canadian orthopaedic surgery residency program showed improved quality of life and overall satisfaction since the implementation of work hour regulations[39]. Most of the studies showing improvement had a night-float system, during which residents were assigned to do eight to twelve-hour night-shift work for a certain period of time which varied between institution, implemented rather than a post-call system during which residents were allowed to go home to rest after a full 24-hour workday.

1.8 Study purpose

As noted previously, most of the current studies on stress in trainees are subjective, being based on questionnaires. Therefore, current literature focuses only on the subjective responses to the behavioral component of stress. Moreover, they have not led to a definitive answer regarding training and working environment optimization and examine the problem in a general way. Further analysis of work conditions and the environment is needed, including examination of specific elements of the work environment. The physiological component to stress has only rarely been evaluated in studies. Heart rate variability has been previously used in Cardiac Surgery[30], Anesthesia residents[8], and General Surgery simulator training[3]. Salivary cortisol level has also been used in some studies as an adjunct to stress evaluation[8,11], however heart rate variability is considered a more sensitive marker of sympathetic response, as well as more sensitive to the timing of the stress application. No studies of this type, however, have been done in orthopaedic surgery. It is logical to think that orthopaedic surgery can present some unique characteristics when compared to the other surgical fields since it requires higher physical demands to perform some tasks. The purpose of this study was to evaluate the physiological responses of orthopaedic surgery staff and trainees during clinical duties. We hypothesized that fellows will present higher levels of stress than the staff and that this will be dictated by the complexity of the procedure performed. In order to analyze the question, we first tested the feasibility of the testing by performing a pilot study. We then extended the study to multiple staff and fellows to evaluate the difference in physiological parameters during different types of procedures. We finally concentrated specifically on the analysis of the differences in physiological parameters between the different surgical approaches used for total hip arthroplasties.

1.9 Bibliography

1. Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Eur Heart J. 1996;17(3):354-81.

2. Agelink MW, Malessa R, Baumann B, Majewski T, Akila F, Zeit T, et al. Standardized tests of heart rate variability: normal ranges obtained from 309 healthy humans, and effects of age, gender, and heart rate. Clin Auton Res. 2001;11(2):99-108.

3. Andreatta PB, Hillard M, Krain LP. The impact of stress factors in simulation-based laparoscopic training. Surgery. 2010;147(5):631-9.

4. Arora S, Aggarwal R, Moran A, Sirimanna P, Crochet P, Darzi A, et al. Mental practice: effective stress management training for novice surgeons. J Am Coll Surg. 2011;212(2):225-33.

5. Cecil J, McHale C, Hart J, Laidlaw A. Behaviour and burnout in medical students. Med Educ Online. 2014;19:25209.

6. Chan S, Debono M. Replication of cortisol circadian rhythm: new advances in hydrocortisone replacement therapy. Ther Adv Endocrinol Metab. 2010;1(3):129-38.

7. Compton MT, Frank E. Mental health concerns among Canadian physicians: results from the 2007-2008 Canadian Physician Health Study. Compr Psychiatry. 2011;52(5):542-7.

8. Eisenach JH, Sprung J, Clark MM, Shanafelt TD, Johnson BD, Kruse TN, et al. The psychological and physiological effects of acute occupational stress in new anesthesiology residents: a pilot trial. Anesthesiology. 2014;121(4):878-93.

9. Gardiner P, Filippelli AC, Lebensohn P, Bonakdar R. The incorporation of stress management programming into family medicine residencies-results of a national survey of residency directors: a CERA study. Fam Med. 2015;47(4):272-8.

10. Goldhagen BE, Kingsolver K, Stinnett SS, Rosdahl JA. Stress and burnout in residents: impact of mindfulness-based resilience training. Adv Med Educ Pract. 2015;6:525-32.

11. Harvey A, Bandiera G, Nathens AB, LeBlanc VR. Impact of stress on resident performance in simulated trauma scenarios. J Trauma Acute Care Surg. 2012;72(2):497-503.

12. Kimo Takayesu J, Ramoska EA, Clark TR, Hansoti B, Dougherty J, Freeman W, et al. Factors associated with burnout during emergency medicine residency. Acad Emerg Med. 2014;21(9):1031-5.

13. Kuhn EW, Choi YH, Schönherr M, Liakopoulos OJ, Rahmanian PB, Choi CY, et al. Intraoperative stress in cardiac surgery: attendings versus residents. J Surg Res. 2013;182(2):e43-9.

14. Leventer-Roberts M, Zonfrillo MR, Yu S, Dziura JD, Spiro DM. Overweight physicians during residency: a cross-sectional and longitudinal study. J Grad Med Educ. 2013;5(3):405-11.

15. Malik M, Camm AJ. Dynamic electrocardiography. Elmsford, N.Y.: Blackwell/Futura; 2004. xviii, 637 p. p.

16. Mann SM, Borschneck DP, Harrison MM. Implementation of a novel night float call system: resident satisfaction and quality of life. Can J Surg. 2014;57(1):15-20.

17. Mata DA, Ramos MA, Bansal N, Khan R, Guille C, Di Angelantonio E, et al. Prevalence of Depression and Depressive Symptoms Among Resident Physicians: A Systematic Review and Meta-analysis. JAMA. 2015;314(22):2373-83.

18. McKinley SK, Petrusa ER, Fiedeldey-Van Dijk C, Mullen JT, Smink DS, Scott-Vernaglia SE, et al. Are there gender differences in the emotional intelligence of resident physicians? J Surg Educ. 2014;71(6):e33-40.

19. Min AA, Sbarra DA, Keim SM. Sleep disturbances predict prospective declines in resident physicians' psychological well-being. Med Educ Online. 2015;20:28530.

20. Mironova TF, Mironov V. Clinical analysis of heart rate variability : introduction to clinical rhythmocardiography and atlas of rhythmocardiograms. Chelyabinsk, Russia: s.n.; 2000. 206 p. p.

21. Morrow G, Burford B, Carter M, Illing J. Have restricted working hours reduced junior doctors' experience of fatigue? A focus group and telephone interview study. BMJ Open. 2014;4(3):e004222.

22. Nixon PG. The human function curve. With special reference to cardiovascular disorders: part I. Practitioner. 1976;217(1301):765-70.

23. Ripp JA, Bellini L, Fallar R, Bazari H, Katz JT, Korenstein D. The impact of duty hours restrictions on job burnout in internal medicine residents: a three-institution comparison study. Acad Med. 2015;90(4):494-9.

24. Robertson D, Biaggioni I. Primer on the autonomic nervous system. 3rd ed. Amsterdam: Elsevier Academic Press; 2012. xxv, 703 p. 28 p. of plates p.

25. Ruotsalainen JH, Verbeek JH, Mariné A, Serra C. Preventing occupational stress in healthcare workers. Cochrane Database Syst Rev. 2014(12):CD002892.

26. Schilling TM, Kölsch M, Larra MF, Zech CM, Blumenthal TD, Frings C, et al. For whom the bell (curve) tolls: cortisol rapidly affects memory retrieval by an inverted U-shaped dose-response relationship. Psychoneuroendocrinology. 2013;38(9):1565-72.

27. Selye H. Stress and the general adaptation syndrome. Br Med J. 1950;1(4667):1383-92.

28. Shanafelt TD, Balch CM, Bechamps GJ, Russell T, Dyrbye L, Satele D, et al. Burnout and career satisfaction among American surgeons. Ann Surg. 2009;250(3):463-71.

29. Sloan S, Krishnamurthy M, Lyon DT, Mitri G, Chyshkevych I, Livert D. Work hour regulations: do we need further changes now? A survey of internal medicine faculty and residents. J Grad Med Educ. 2009;1(2):201-7.

30. Song MH, Tokuda Y, Nakayama T, Sato M, Hattori K. Intraoperative heart rate variability of a cardiac surgeon himself in coronary artery bypass grafting surgery. Interact Cardiovasc Thorac Surg. 2009;8(6):639-41.

31. Stauss HM. Heart rate variability. Am J Physiol Regul Integr Comp Physiol. 2003;285(5):R927-31.

32. Umetani K, Singer DH, McCraty R, Atkinson M. Twenty-four hour time domain heart rate variability and heart rate: relations to age and gender over nine decades. J Am Coll Cardiol. 1998;31(3):593-601.

33. Wang Z, Xie Z, Dai J, Zhang L, Huang Y, Chen B. Physician burnout and its associated factors: a cross-sectional study in Shanghai. J Occup Health. 2014;56(1):73-83.

34. Weight CJ, Sellon JL, Lessard-Anderson CR, Shanafelt TD, Olsen KD, Laskowski ER. Physical activity, quality of life, and burnout among physician trainees: the effect of a team-based, incentivized exercise program. Mayo Clin Proc. 2013;88(12):1435-42.

35. West CP, Huschka MM, Novotny PJ, Sloan JA, Kolars JC, Habermann TM, et al. Association of perceived medical errors with resident distress and empathy: a prospective longitudinal study. JAMA. 2006;296(9):1071-8.

36. Widmaier EP, Raff H, Strang KT. Vander's human physiology : the mechanisms of body function. Fourteenth edition. ed. New York, NY: McGraw-Hill Education; 2016. 1 volume (various pagings) p.

37. Wrenn K, Lorenzen B, Jones I, Zhou C, Aronsky D. Factors affecting stress in emergency medicine residents while working in the ED. Am J Emerg Med. 2010;28(8):897-902.

38. Yerkes RM, Dodson JD. The relation of strength of stimulus to rapidity of habit-formation. J Comp Neurol Psychol. 1908;18(5):1550-7149.

39. Zahrai A, Chahal J, Stojimirovic D, Schemitsch EH, Yee A, Kraemer W. Quality of life and educational benefit among orthopedic surgery residents: a prospective, multicentre comparison of the night float and the standard call systems. Can J Surg. 2011;54(1):25-32.

40. Zis P, Anagnostopoulos F, Sykioti P. Burnout in medical residents: a study based on the job demands-resources model. ScientificWorldJournal. 2014;2014:673279.

Chapter 2

2 Physiological and psychological responses to surgery and non-surgery days in orthopaedic surgeons: a pilot study.

2.1 Introduction

Any challenge, real or perceived, to physiological homeostasis causes stress and counter-regulatory responses. These responses are multi-functional and may include molecular, physiological, cognitive and/or behavioral changes. Nonetheless, the body is always under a certain amount of stress, as physiological homeostasis is maintained under changing internal and external environments. Elevated stress improves physical and mental performance in a variety of activities, however, this occurs only up to a point after which performance declines and health is negatively affected[14].

The surgeon, surgical team, and surgical trainees are exposed to physical and mental stress during surgery. The cumulative effect of this stress can affect not only tolerable work capacity by increasing the incidence of burnout[26], but may also result in the deterioration of the quality of patient care[26]. The efficiency, efficacy, and the surgeon's skill levels may be negatively affected if the surgeon or other members of the operative team are experiencing elevated stress[3]. Moreover, the learning environment may deteriorate, impeding the surgical trainees' ability to acquire new skills[8].

Unfortunately, medical and surgical training are not immune to excessive stress. A large study examined burnout in an internal medicine residency group, regardless of whether residents met the criteria for burnout or not[19]. The participants in this study most often rated inadequate sleep, frequently working shifts longer than 24 hours and inadequate leisure time as major stresses. These stresses could result from, or could cause, higher incidences of physiological stress or potentiate experienced stresses. For example, acute sleep deprivation is associated with impaired autonomic regulation of the heart[27]. Work stress, shift work, and length of shift are associated with reduced cardiovascular and mental health[22,24]. Inadequate leisure time leads individuals to exercise less and have less family time[25]. Moreover, residents exhibit poor dietary practices during residency[13], that would undoubtedly be a part of an increase in the likelihood of reduced health outcomes, poor performance, and reduced patient care[5]. These events are not limited to residents, but may be common in practicing surgeons as well. For example, in a population of surgeons, burnout has been reported as high as 40% in a large (>7000 individuals) sample of American surgeons[5].

The perception of fatigue tends to correlate well with actual physical fatigue[4]. Moreover, physical stress is associated with increases in heart rate, breathing rate and body temperature. Heart rate variability (HRV) has been demonstrated to be one of the best methods for autonomic stress assessment[20]. HRV can be calculated using frequency domain analysis of the beat-to-beat variation in heart rate (HR). Within the frequency domain analysis, the low frequency (LF) component is associated with sympathetic and vagal modulation of the heart while the high frequency (HF) component is representative of vagal modulation of the heart. Consequently, the ratio of low to high frequencies (LF/HF ratio) is representative of the balance between sympathetic and vagal activity. A higher ratio represents a predominant sympathetic response, and therefore a period of higher stress while a lower ratio represents a predominantly parasympathetic response. Measuring HRV provides greater sensitivity than measuring HR alone, as an elevated HR alone may be due to physical exertion in the absence of other types of stress (e.g. anxiety)[20]. This type of observation has been used in sports training in order to identify stressors and optimize the athlete's training and overall performance[16]. However, few studies have analyzed actual physiological responses during surgical practice[7-9,11], and what factors may modify (i.e. attenuate) these responses. Consequently, the goal of this study was to track physiological and psychological responses to common hip and knee surgeries, as well as during clinic and rest days in an expert orthopaedic surgeon.

2.2 Material and methods

Consent was obtained from an expert surgeon from a single institution, the participant was fully explained the methods to be used throughout the study. An independent research assistant, who is not one of the main investigators, collected all data. All procedures received institutional human research ethics clearance from the institutions involved in the study.

The participant completed the State-Trait Anxiety Questionnaire (STAI, Y1 and Y2) at the beginning of the study (Appendix B). The STAI is a validated tool used to measure the subjective level of state (i.e. how anxious a subject is in the present situation) and trait (i.e. the tendency to perceive a given situation as stressful) anxiety[21]. It consists of 40 questions (20 question for state and 20 questions for trait anxiety) that measure self-reported scales of feelings of apprehension, tension, nervousness, and worry. Higher scores in this test indicate higher levels of anxiety as a stable trait (STAI-Y1) or acutely (STAI-Y2). The test was administered to the participant on day 1 of the study, which was a non-surgical day as well as at the commencement of the other 24-hour non-surgical work days in order to establish anxiety-stress levels experienced. On surgery work days, the participant was administered the STAI-Y2 (state) questionnaire at the beginning of the day prior to surgeries, immediately prior to, and after, individual surgeries.

The participant was also instructed to wear an Equivital EQO2 HRV holter monitor (Vivonoetics, San Diego, California) for 6-8 hours on non-surgery workdays, on surgery workdays for the entirety of the respective workdays and for 6-8 hours during the rest day. Physiological data collected by the device included electrocardiogram (EKG), respiratory rate using strain gauge technology, infrared skin temperature. All data was sent electronically to the investigators for analysis of the data and calculation of HR and HRV using VivoSense® Software (Vivonoetics, San Diego, California). For analysis of HRV, the raw data was first processed with automated filters to exclude noise in the signal. A representative tracing of a surgery day showing EKG, trend HR, 5 minute segmented HRV, and trend BR is shown in appendix C for each surgery for which data was collected, analysis was performed starting 10 minutes prior to the start of the surgery (Pre-operative period) and up to 10 minutes following that procedure (Post-operative period). The results of the STAI questionnaires allowed for comparisons with the data acquired via the HR monitor, to determine whether perceived stress correlates with physiological changes.

Given that we observed the data for a single individual, simple correlation analysis was made between the data collected from the questionnaire and the physiological responses noted with the monitoring.

2.3 Results

One expert orthopaedic surgeon specialized in adult hip and knee reconstruction with 3 years of practice working at a single teaching hospital facility was included in the study. Data was collected for a total of 10 days, including 8 surgery days, 1 clinic day and 1 “off”/rest day. A total of 22 surgeries were performed during that period, including fifteen total hip arthroplasty (THA) and seven total knee arthroplasty (TKA).

Mean HR was 66 beats per minute (bpm) during the rest day and 71 bpm during clinic day. The HR during surgery days was elevated throughout the day regardless of the period measured (Fig. 2-1 and 2-2) HR was higher during the perioperative and intraoperative period performing THA compared to TKA. Before THA and TKA, the mean HR was 77 bpm and 75 bpm respectively. Mean heart rate increased to 87 bpm (SD 6.6bpm) during THA and to 76.5 bpm (SD 4.2bpm) during TKA. The heart rate post-operatively never reached the pre-operative levels after THA (mean 82 bpm, SD 5.0bpm), but did after TKA (mean 75 bpm, SD 2.4bpm).

Skin temperature was similar during the rest day and clinic days. During surgery days, it was one degree higher than the other days throughout the day. No differences were noted when comparing between the different type of surgeries performed.

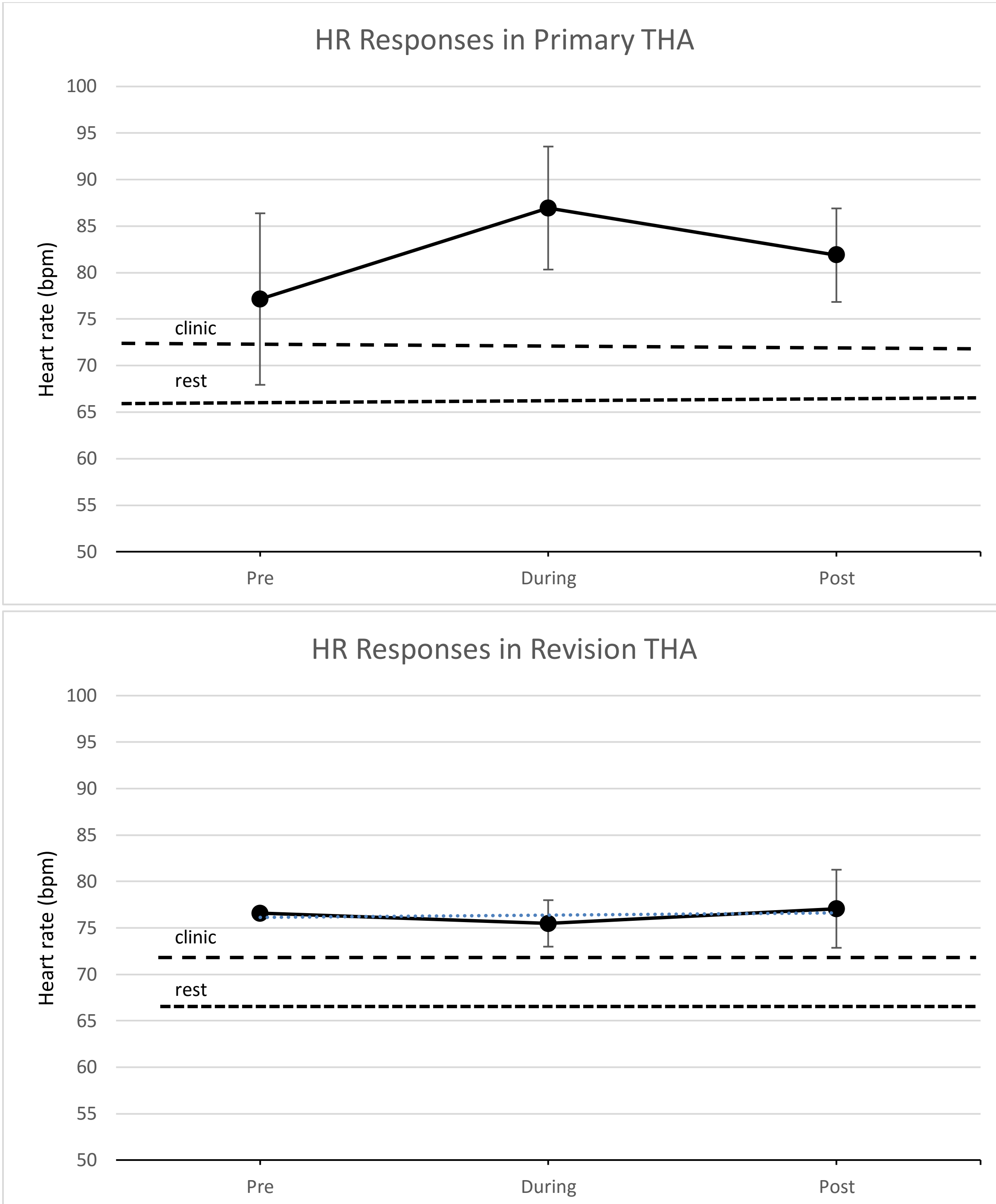
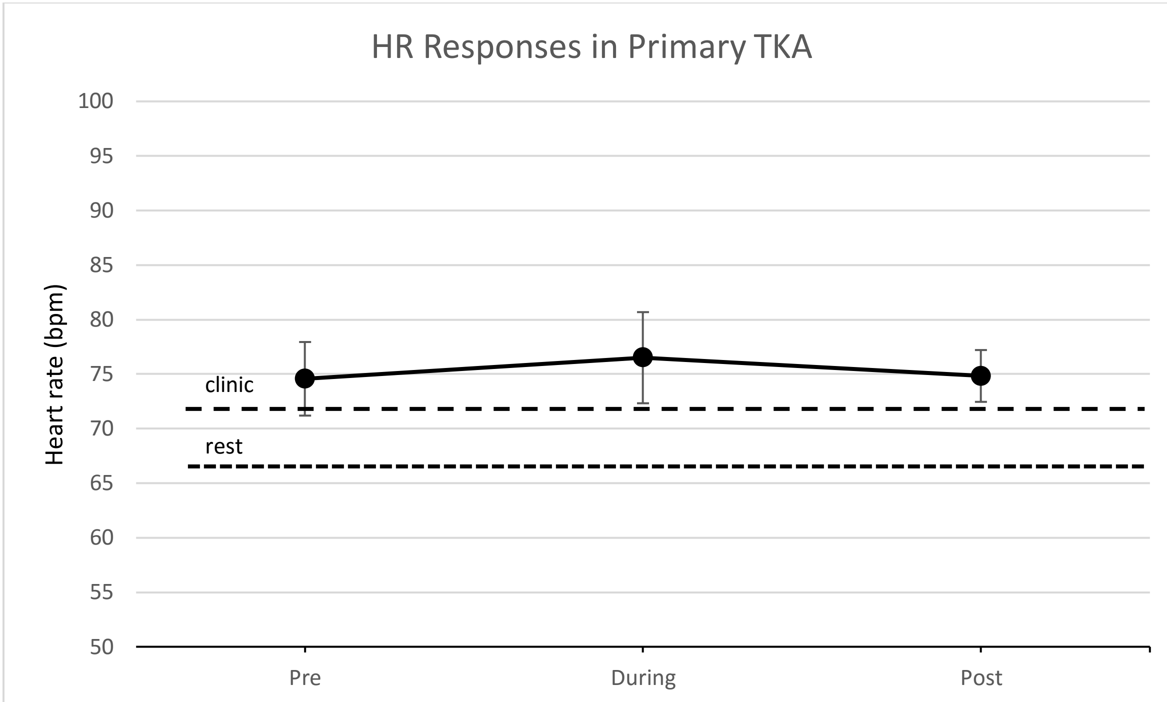


Figure 2-1 Mean heart rate recorded in (a) Primary THA (pTHA) and (b) Revision THA (rTHA) (OR data shown with solid line)



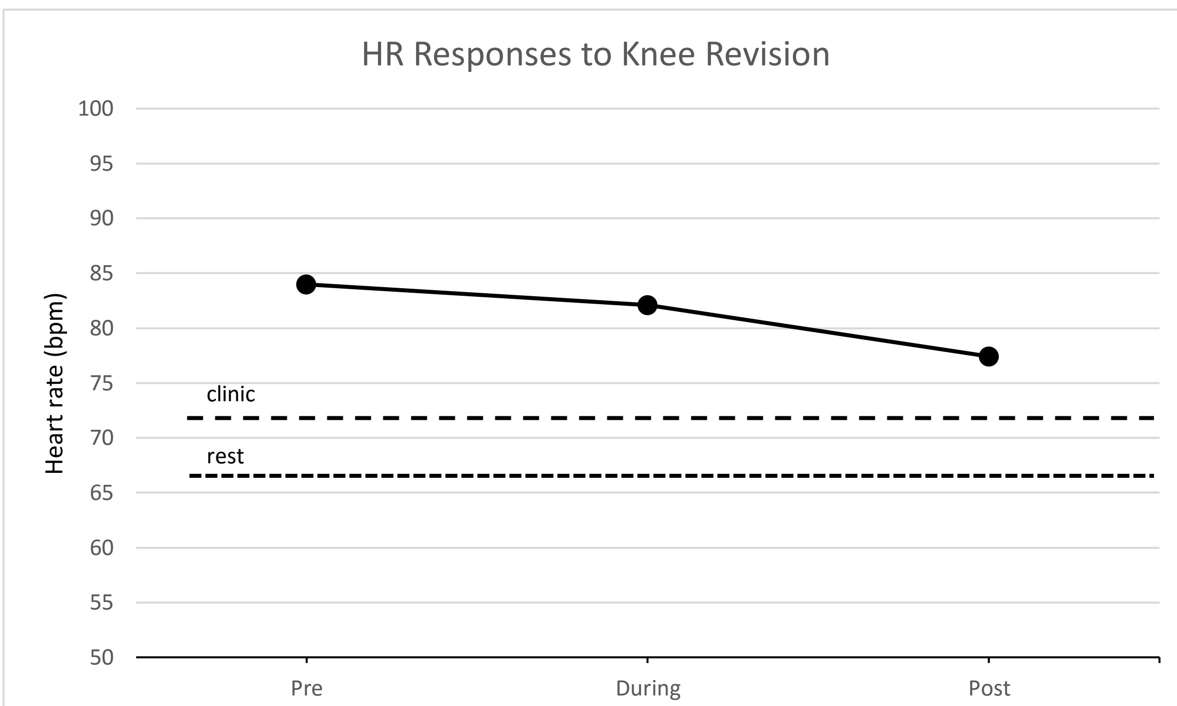


Figure 2-2 Mean heart rate recorded in (a) Primary TKA (pTKA) and (b) Revision TKA (rTKA) (OR data shown with solid line). Lack of error bars indicate only 1 recording of this procedure.

Respiratory rate was elevated on surgery days compared to the rest (17 breaths per minute) and clinic day (15.3 breaths per minutes). Respiratory rate was increased before starting any procedure (Mean THA 22.5 breaths per minute, SD 4.3 - Mean TKA 19.9 breaths per minute, SD 2.6). It remained elevated but at slightly lower levels during THA (Mean 20.2 breaths per minute, SD 2.2), however reached similar levels to rest days during TKA (Mean 17.4 breaths per minute, SD 2.8). In the immediate postoperative period, the respiratory rate remained at the same levels as intraoperative in both THA (Mean 21.5 breaths per min, SD 4.5) and TKA (Mean 17.9 breaths per min, SD 0.1).

HRV was measured as a ratio of low frequency to high frequency (LF/HF). This ratio was slightly increased before any procedure (Fig. 2-3 and 2-4), affected more before THA (mean LF/HF 4.39, SD 4.05) than in TKA (mean LF/HF 2.20, SD 1.62). It was even higher during and after any procedure. During a THA, the LF/HF reaches a mean of 7.30 (SD 3.75) and remains high after the procedure to a mean of 6.80 (SD 4.45). Similarly, during a TKA, the LF/HF ratio is also increased but to a smaller extends reaching a mean 5.09 (SD 2.46) intraoperatively and mean of 4.46 (SD 2.90) after the procedure. Given normal values of heart rate variability have not been yet established and are depended on multiple factors including the age, gender and fitness level of an individual[1,23], the rest value is used here as a reference of comparison.

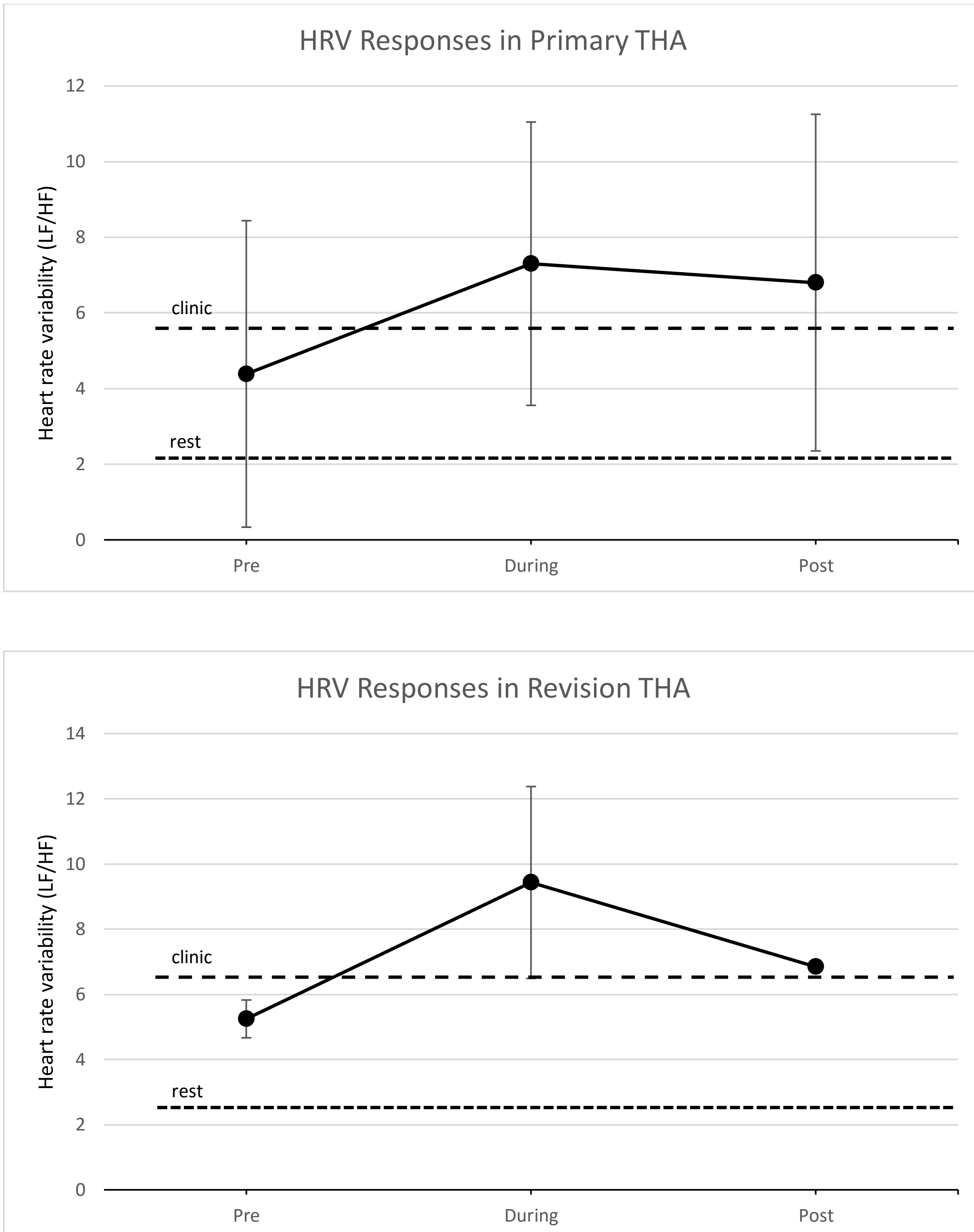


Figure 2-3 HRV recorded in (a) Primary THA and (b) Revision THA (OR data shown with solid line)

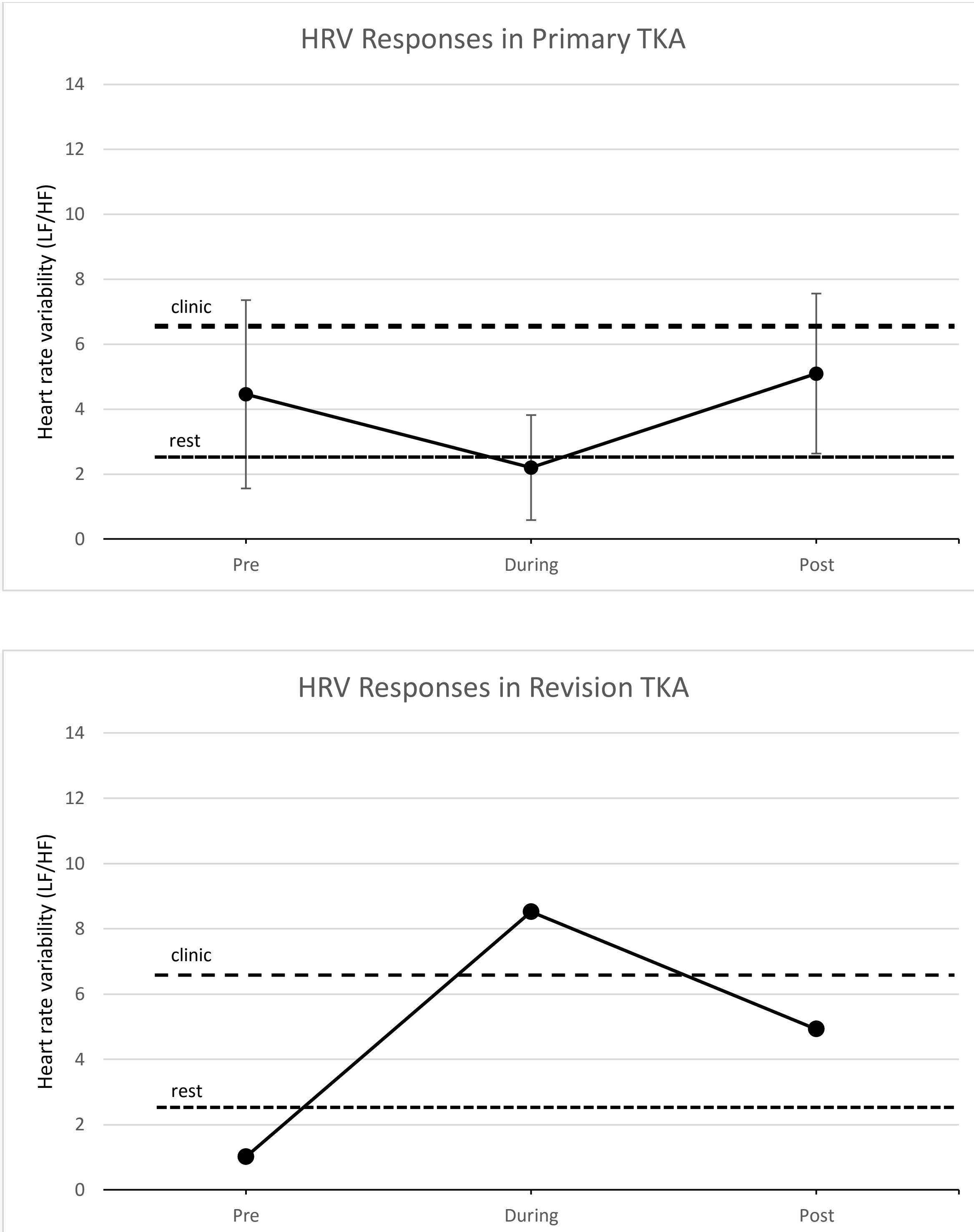


Figure 2-4 HRV recorded in (a) Primary TKA and (b) Revision TKA (OR data shown with solid line). Lack of error bars indicate only 1 recording of this procedure.

Evaluating the responses to the STAI questionnaire before and after any procedure, average score was consistently higher preoperatively than postoperatively. Before THA, the STAI questionnaire score has a mean of 32.9 compare to 22.1 after the procedure. When performing TKA, the STAI questionnaire score reaches a mean of 30.5 preoperatively compare to 20 postoperatively. There was no correlation noted between the STAI scores and physiological responses like HR (R^2=0.15683) or HRV (R^2=0.11333).

2.4 Discussion

The aim of this study was to track physiological and psychological responses to common hip and knee surgeries, as well as during clinic and "off" days in an expert orthopaedic surgeon. Similar pilot studies have been done in other surgical specialties[15,21]. However, this study is the first involving common orthopaedic surgery procedures and physiological responses, since only questionnaire-based studies have been done in this field[17]. Common orthopaedic surgical procedures are unique since they are much more physically demanding than other type of surgeries. The physicality of these surgeries adds to the physiological responses experienced by the surgeon to the stressors surrounding the surgery itself. This makes it even more important to use HRV as our measurement tool to perform such analysis.

Physiological responses tended to be different between the type of procedures performed. Specifically, they were higher during THA compared to TKA. Multiple factors could potentially explain such results. First, this could be related to the increased physical stress experienced during the procedure. Second, the complexity of the procedure might differ between the THA and the TKA for the sample of operations for which data was collected. Third, the surgeon participating in this pilot study performed anterior approach THA at the time of data collection. The surgeon was the only surgeon performing the THA using this approach at our institution at that time. Therefore, the surgeon might have experienced higher stress levels during THA, as other members of the surgical team (nurses and trainees) were relatively inexperienced with this surgical technique. Future study with multiple surgeons performing a variety of surgical techniques will help to further explore these issues.

Moreover, this study clearly shows that despite the minimal amount of physical activity happening in the immediate preoperative period, the physiological responses during that period are higher than rest days or clinic days. When combined with the increased scores in the STAI questionnaires during the same period, we understand that a surgeon has an increased level of stress during the surgery days. This relates probably to surgeon related psychological stresses of patient safety, self-imposed demands, and high achievement standards.

The STAI questionnaire has been previously used in the literature to evaluate stress levels in surgeons[2,3]. However, no studies before correlated STAI scores with physiological responses. It is difficult to establish such correlation in our limited observations. However, we were able to observe a tendency towards increased physiological responses in the postoperative period in contrast to STAI scores that were similar to the rest day scores during that same postoperative timeframe. This could indicate that most of the physiological response observed in the postoperative period is related to physical strain recovery rather than response to stressors.

The limitations of this study are as follows. First, it is difficult to differentiate between physical and mental stress during surgery given the physical nature of the tasks and the inability to get subjective ratings of stress. Second, noise in the EKG tracing collected might have interfered with the results obtained. We anticipate this effect would be small as the Vivosense software uses automatic filters to diminish the effect of the noise on the collected data as much as possible. Third, the results obtained from the STAI questionnaires could have been biased since filling these questionnaires on multiple times during a same day could lead to acute repetition of data by the participant and, therefore, might influence the results obtained.

The results of this study show the feasibility in detecting physiological levels of stress in orthopaedic surgeons in their everyday work related activities. This study will be used as the basis to a larger scale study including multiple surgeons, trainees during those surgeries using different types of approaches and other orthopaedic procedures. As competency based training models are becoming increasingly implemented, evaluating different stressors surrounding the surgical training will eventually lead to improvements in the learning environment for the surgical trainees, and lead to more efficient and healthier training. Of particular importance will be correlating the timing of stress (i.e. at what surgical step) for surgeons and surgical trainees to understand if different interventions may be required at different times of a given procedure.

2.5 Conclusion

In conclusion, this pilot study demonstrates that an established surgeon experiences increased physiologic stress and psychologic stress on days that surgery is performed. Surgeons experience much lower stress and anxiety on leisure days and days spent in clinic with outpatients. It is notable that different levels of stress are encountered in different types of procedures. Further investigation to evaluate and identify stressors in the hospital setting, identify their effect on learning and practice, and to provide interventions to optimize the environment for both the surgeon as well as other members of the health care provider team and trainees is required.

2.6 References

1. Agelink MW, Malessa R, Baumann B, Majewski T, Akila F, Zeit T, et al. Standardized tests of heart rate variability: normal ranges obtained from 309 healthy humans, and effects of age, gender, and heart rate. Clin Auton Res. 2001;11(2):99-108.

2. Andreatta PB, Hillard M, Krain LP. The impact of stress factors in simulation-based laparoscopic training. Surgery. 2010;147(5):631-9.

3. Arora S, Aggarwal R, Moran A, Sirimanna P, Crochet P, Darzi A, et al. Mental practice: effective stress management training for novice surgeons. J Am Coll Surg. 2011;212(2):225-33.

4. Bautmans I, Gorus E, Njemini R, Mets T. Handgrip performance in relation to self-perceived fatigue, physical functioning and circulating IL-6 in elderly persons without inflammation. BMC Geriatr. 2007;7:5.

5. Cecil J, McHale C, Hart J, Laidlaw A. Behaviour and burnout in medical students. Med Educ Online. 2014;19:25209.

6. Cohen JS, Leung Y, Fahey M, Hoyt L, Sinha R, Cailler L, et al. The happy docs study: a Canadian Association of Internes and Residents well-being survey examining resident physician health and satisfaction within and outside of residency training in Canada. BMC Res Notes. 2008;1:105.

7. Eisenach JH, Sprung J, Clark MM, Shanafelt TD, Johnson BD, Kruse TN, et al. The psychological and physiological effects of acute occupational stress in new anesthesiology residents: a pilot trial. Anesthesiology. 2014;121(4):878-93.

8. Flinn JT, Miller A, Pyatka N, Brewer J, Schneider T, Cao CG. The effect of stress on learning in surgical skill acquisition. Med Teach. 2016;38(9):897-903.

9. Hernández-Gaytan SI, Rothenberg SJ, Landsbergis P, Becerril LC, De León-León G, Collins SM, et al. Job strain and heart rate variability in resident physicians within a general hospital. Am J Ind Med. 2013;56(1):38-48.

10. Ishak WW, Lederer S, Mandili C, Nikravesh R, Seligman L, Vasa M, et al. Burnout during residency training: a literature review. J Grad Med Educ. 2009;1(2):236-42.

11. Kuhn EW, Choi YH, Schönherr M, Liakopoulos OJ, Rahmanian PB, Choi CY, et al. Intraoperative stress in cardiac surgery: attendings versus residents. J Surg Res. 2013;182(2):e43-9.

12. Malliani A, Pagani M, Lombardi F, Cerutti S. Cardiovascular neural regulation explored in the frequency domain. Circulation. 1991;84(2):482-92.

13. Mota MC, De-Souza DA, Rossato LT, Silva CM, Araújo MB, Tufik S, et al. Dietary patterns, metabolic markers and subjective sleep measures in resident physicians. Chronobiol Int. 2013;30(8):1032-41.

14. Nixon PG. The human function curve. With special reference to cardiovascular disorders: part I. Practitioner. 1976;217(1301):765-70.

15. Phitayakorn R, Minehart RD, Hemingway MW, Pian-Smith MC, Petrusa E. Relationship between physiologic and psychological measures of autonomic activation in operating room teams during a simulated airway emergency. Am J Surg. 2015;209(1):86-92.

16. Plews DJ, Laursen PB, Stanley J, Kilding AE, Buchheit M. Training adaptation and heart rate variability in elite endurance athletes: opening the door to effective monitoring. Sports Med. 2013;43(9):773-81.

17. Sargent MC, Sotile W, Sotile MO, Rubash H, Barrack RL. Quality of life during orthopaedic training and academic practice. Part 1: orthopaedic surgery residents and faculty. J Bone Joint Surg Am. 2009;91(10):2395-405.

18. Shanafelt TD, Balch CM, Bechamps GJ, Russell T, Dyrbye L, Satele D, et al. Burnout and career satisfaction among American surgeons. Ann Surg. 2009;250(3):463-71.

19. Shanafelt TD, Bradley KA, Wipf JE, Back AL. Burnout and self-reported patient care in an internal medicine residency program. Ann Intern Med. 2002;136(5):358-67.

20. Song MH, Tokuda Y, Nakayama T, Sato M, Hattori K. Intraoperative heart rate variability of a cardiac surgeon himself in coronary artery bypass grafting surgery. Interact Cardiovasc Thorac Surg. 2009;8(6):639-41.

21. Spielberger CD, Gorsuch RL, Lushene RE. STAI manual for the Stait-Trait Anxiety Inventory ("self-evaluation questionnaire"). Palo Alto, Calif: Consulting Psychologists Press; 1970. 24 p. p.

22. Thomas C, Power C. Shift work and risk factors for cardiovascular disease: a study at age 45 years in the 1958 British birth cohort. Eur J Epidemiol. 2010;25(5):305-14.

23. Umetani K, Singer DH, McCraty R, Atkinson M. Twenty-four hour time domain heart rate variability and heart rate: relations to age and gender over nine decades. J Am Coll Cardiol. 1998;31(3):593-601.

24. Vrijkotte TG, van Doornen LJ, de Geus EJ. Effects of work stress on ambulatory blood pressure, heart rate, and heart rate variability. Hypertension. 2000;35(4):880-6.

25. Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. CMAJ. 2006;174(6):801-9.

26. West CP, Huschka MM, Novotny PJ, Sloan JA, Kolars JC, Habermann TM, et al. Association of perceived medical errors with resident distress and empathy: a prospective longitudinal study. JAMA. 2006;296(9):1071-8.

Chapter 3

3 Comparison of physiological and psychological responses to clinical duties between orthopaedic surgeons and trainees

3.1 Introduction

Physical and mental stress is present within the practice of healthcare professionals affecting negatively the quality of the services provided to the population[1,17] and leading to mental exhaustion of the individuals involved[17]. Medical training exposes the different level trainees to similar stressors leading to high incidence of stress and stress-related psychiatric conditions such as depression[8]. Although some of those factors have been identified[10,13-16,18] and attempts have been made to minimize them, this problem is still actively present[18]. This stressful environment can potentially affect negatively the ability to acquire new skills adequately[5].

It has always been difficult to quantify objectively stress objectively. One of the methods that has been shown to be the most efficient to assess the activity of the autonomic nervous system and, therefore, quantify the effect of stress has been the evaluation of heart rate variability (HRV)[13]. Such analysis has been previously used in athletes to evaluate stress experienced and recovery[11]. Few studies have been done in surgery[4-7]. Previously, we verified the feasibility of using this type of analysis to evaluate the physiological changes happening in the body of an orthopaedic surgeon during his clinical duties. Consequently, the goal of this study was to track physiological and psychological responses to common hip and knee surgeries as well as during clinic days in a group of orthopaedic surgeons and their trainees.

3.2 Material and methods

Consent was obtained from the adult hip and knee reconstruction specialized surgeons and the clinical fellows training in a single institution from July 2015 to June 2016. The participant was fully informed about the methods to be used throughout the study. Participants that had cardiovascular medical comorbidities such as cardiac arrhythmias, other cardiac or respiratory diseases requiring to take medications influencing cardiovascular parameters were excluded from the study. Other exclusion criteria included participants unable to wear the monitors and participants with BMIs lower than 18 or higher than 35. An independent research assistant, who was not one of the main investigators, collected all data. All procedures received institutional human research ethics clearance from the institutions involved in the study.

The participants underwent a baseline stress test at some point during the study depending on their time availability. The test was performed in a hospital setting under the supervision of an independent physician. The participants were asked to refrain from drinking caffeine on the day of the test. Once participants arrived at the hospital, they first completed a health check questionnaire. Their height and weight were then obtained using a stadiometer. Three initial baseline blood pressure measurements were recorded with a 2-minute interval between each reading prior to the start of the test in a sitting position. A 12-lead EKG was then placed on the participants and they started to exercise on the treadmill in an increasing difficulty fashion using the Bruce protocol (Appendix D). At each difficulty level, the participant was required to evaluate how they were feeling using the Borg scale as a reference (Appendix E). The treadmill part of the test was stopped at the moment the participant requested to stop. The reason for stopping was recorded in the participant's chart. Maximum heart rate was recorded at that moment. The participant was seated at that point and serial EKG and blood pressure measurements were taken every 2 minutes for a total of 10 minutes post exercise. Maximum heart rate was calculated and used to calculate the percentage of maximal effort (%HRmax) reached during the different activities evaluated as a marker of intensity of the procedure.

Concurrently, psychological assessment was performed using State-Trait Anxiety Questionnaire (STAI) (Appendix B), questionnaire filled by each participant immediately prior to each surgery and after individual surgeries were completed.

Correlation analysis was made between the data collected from the questionnaire and the physiological responses noted with the monitoring. The data collected from staff and fellows from the monitoring included heart rate, respiratory rate and heart rate variability was compared using T-test to identify for differences in the mean levels recorded.

Difference between the data recorded while performing different roles was analysed using one-way ANOVA. Post-hoc analysis was also performed.

3.3 Results

A total of three joint reconstruction orthopaedic surgeons working in a single academic institution and five orthopaedic surgery clinical fellows training in the same institution from July 2015 to June 2016 were included in the study. No participants were excluded from the study. Data from the stress test was collected from all the participants. Data was collected for a total of 32 days, including 7 clinic days and 25 surgery days. Data was recorded from 11 total hip arthroplasty (THA) and 20 total knee arthroplasty (TKA) cases.

Mean heart rate (HR) and %HRmax were not significantly different between staff and fellows throughout the surgery days regardless of the role occupied during both primary THA and TKA (Figure 3-1). In a similar fashion, there was no significant difference between staff (mean 75 bpm, SD 6.0) and fellows (mean 68 bpm, SD 11.9) during clinic days ($p=0.191$). Analysis of the HR results by role assumed by surgeons and trainees during primary THA and primary TKA are indicated in Figure 3-2 and 3-3, respectively. In THA, post-hoc analysis revealed that staff surgeons had significantly increased heart rates in the primary surgeon role compared to assistant role and clinic days. This was true when doing the analysis of the HR during the surgery but also in the preoperative and postoperative period. Moreover, staff tend to show a higher %HRmax while performing the surgery as primary surgeon (mean 77%, SD 17.3) compared to assisting (mean 56%, SD 15.4) and clinic days (mean 54%, SD 18.0) without statistical significance (p=0.082). In comparison, fellows involved in a THA case did not show significant difference between the assistant, the primary surgeon role and clinic days, with a tendency of increased heart rate during OR days compared to clinic days. Similarly, %HRmax was overall statistically similar between primary surgeon role (mean 74%, SD 26.6), assistant role (mean 69%, SD 20.1) and clinic days (mean 60%, SD 18.9). When analyzing the data obtained during TKA, staff also had significantly increased HR while performing those cases as primary surgeon compared to assisting to the surgery or during clinic days. Analysis of the %HRmax showed similar results with primary surgeon role (mean 73%, SD 23.6) presenting significantly higher intensity than during an assisting role (mean 49%, SD 4.8, p=0.006) and non-significantly higher than clinic days (mean 54%, SD 18.0, p=0.075). Post-hoc analysis showed tendency towards increased heart rate in the preoperative (p=0.088) and postoperative period (p=0.115) between the different roles assumed during TKA but no difference noted intraoperatively. On the other hand, post-hoc analysis of the data obtained from the fellows supported a difference between clinic days and OR days. However, when separating the data on the basis of the role that was assumed by the fellows during those cases, no difference was noted then. This was true for all time period including the preoperative, intraoperative and postoperative period. Similarly, no statistical difference (p=0.833) was noted in %HRmax between primary surgeon role (mean 63%, SD 3.8), assistant role (mean 59%, SD 16.8) and clinic days (mean 60%, SD 18.9).

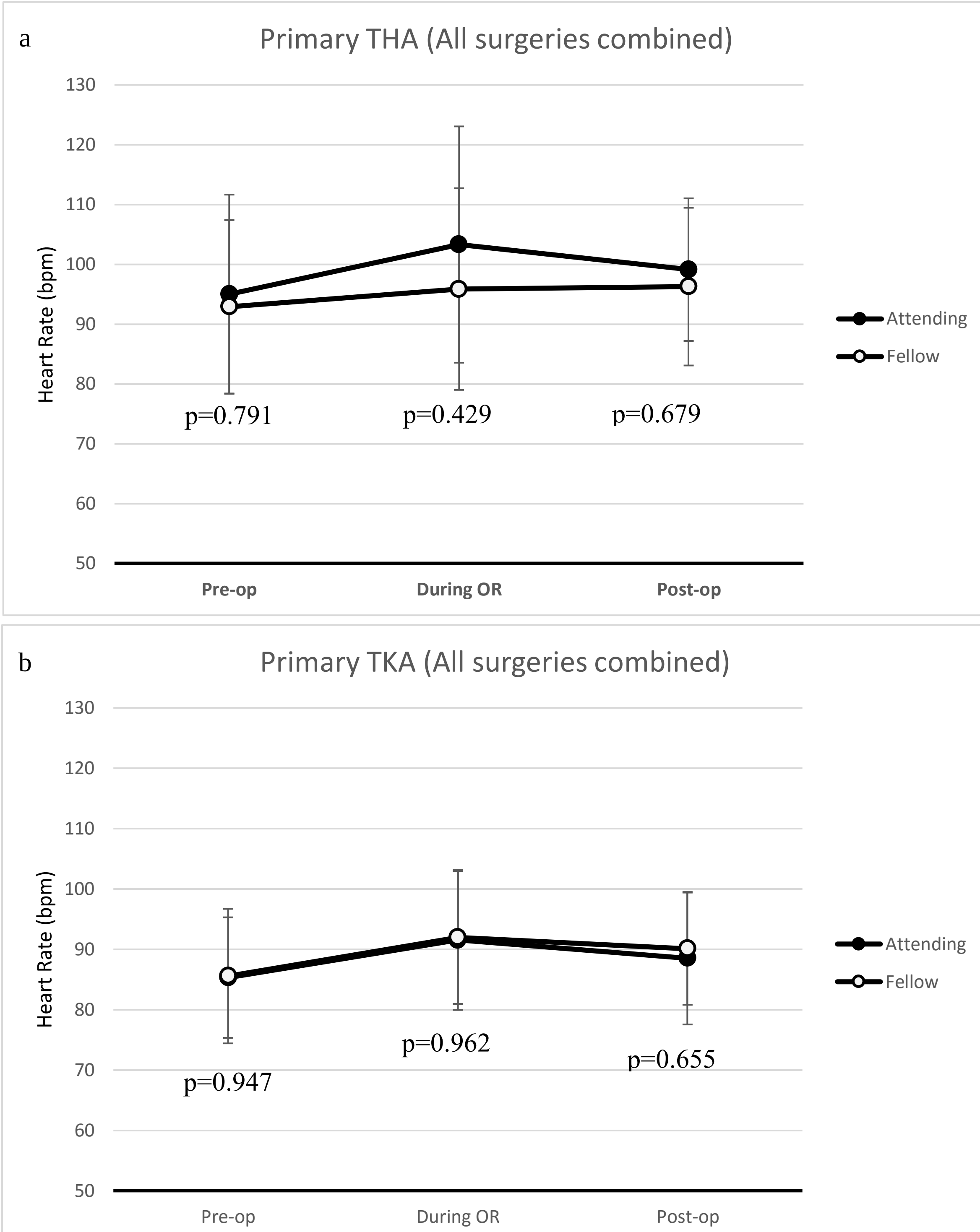


Figure 3-1 Heart rate regardless of role occupied during a) total hip arthroplasty and b) total knee arthroplasty

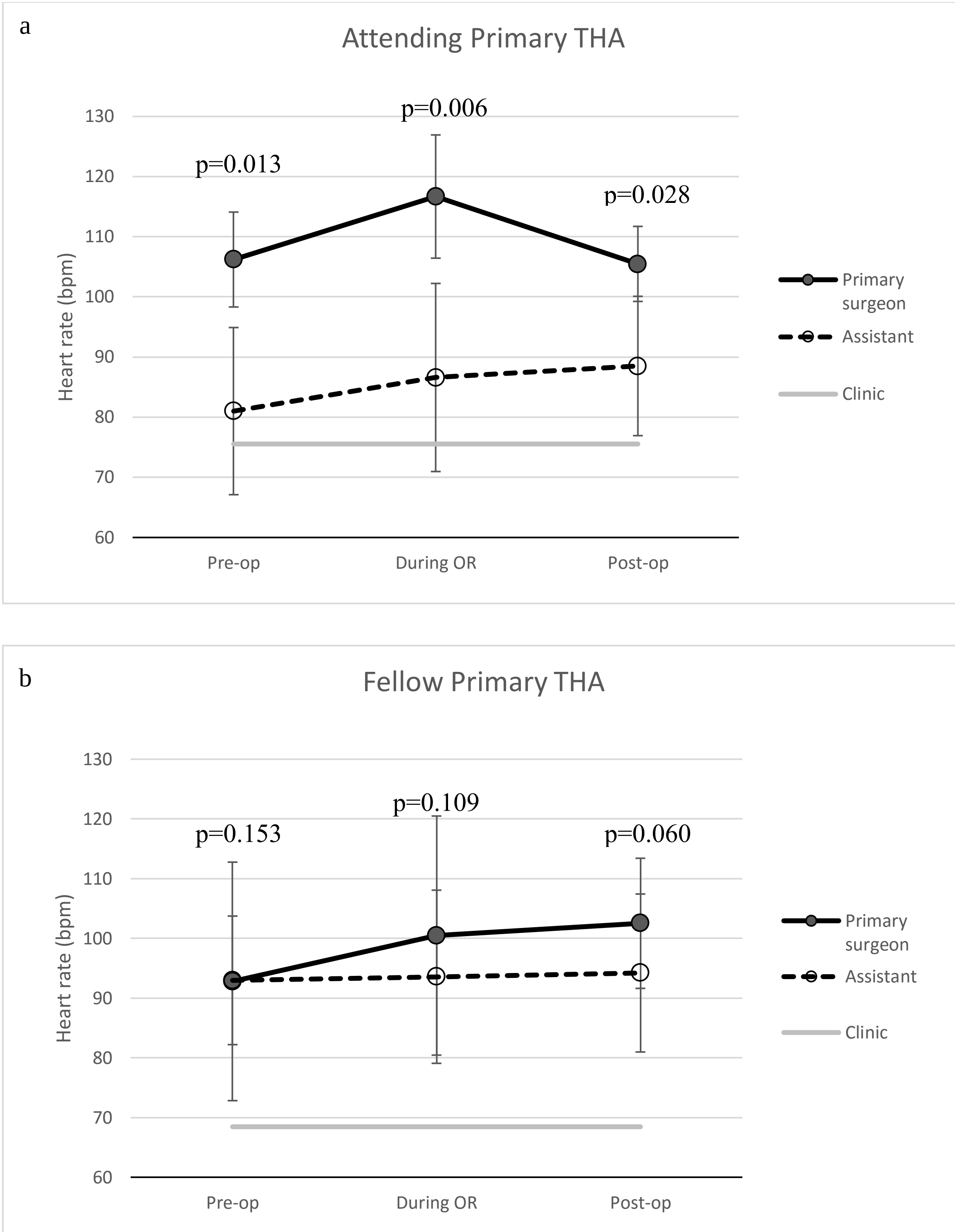


Figure 3-2 Heart rate during total hip arthroplasty by a) Staff and b) Clinical fellows

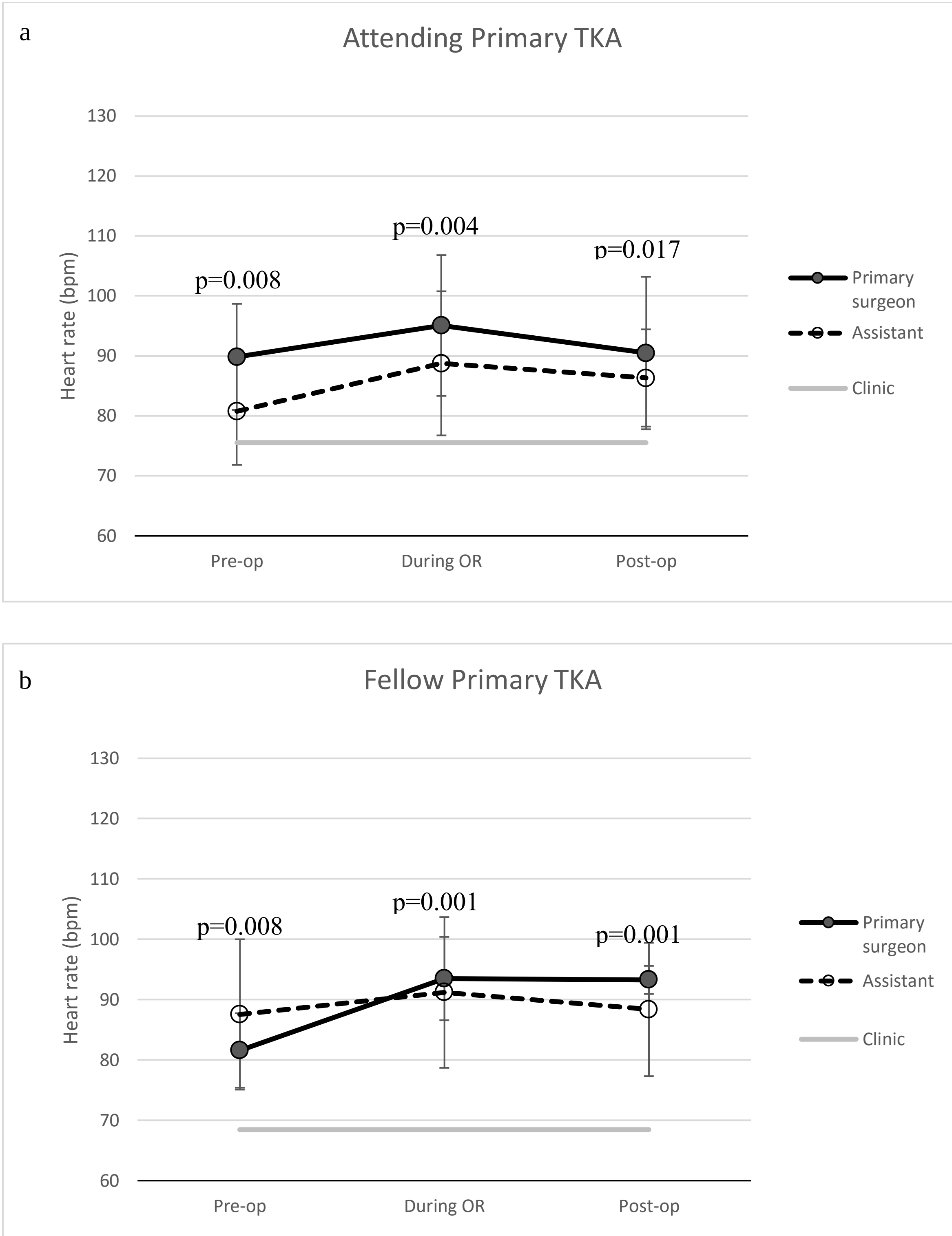


Figure 3-3 Heart rate during total knee arthroplasty by a) Staff and b) Clinical fellows

Respiratory rate results during THA and TKA are shown in Figure 3-4 and 3-5 respectively. For THA, staff failed to show any significant difference in their breathing rate when comparing OR days and clinic days. Assuming a primary surgeon role did not show any significant difference compare to an assistant role or clinic days throughout the analyzed period. Fellows also did not show any significant difference between their respiratory rate during clinic days and OR days, even after analysis of the data based on the role assumed during those cases throughout the recorded period. For TKA, staff also failed to show any significant difference in their breathing rate when comparing OR days and clinic days. A role based analysis also failed to show any difference between the assumed role during those type of cases. On the other hand, fellows showed significantly higher breathing rate in the primary surgeon role compare to clinic days only during the surgery itself. Post-hoc analysis showed that they had a tendency towards higher breathing rate when they were assisting a TKA case ($p=0.118$). The preoperative and postoperative periods around a TKA failed to show statistical significance in breathing rate compared to clinic days.

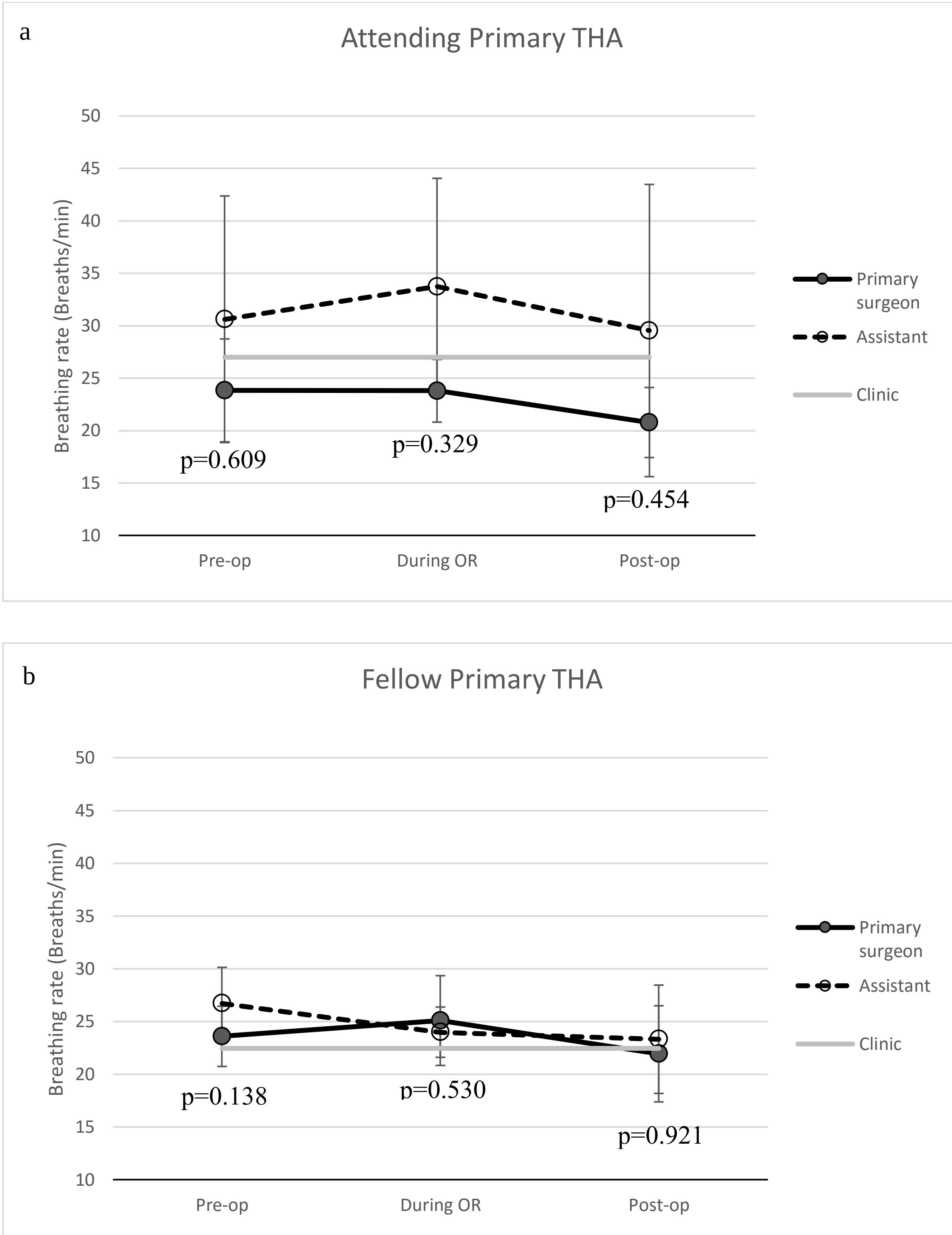


Figure 3-4 Breathing rate during total hip arthroplasty by a) Staff and b) Clinical fellows

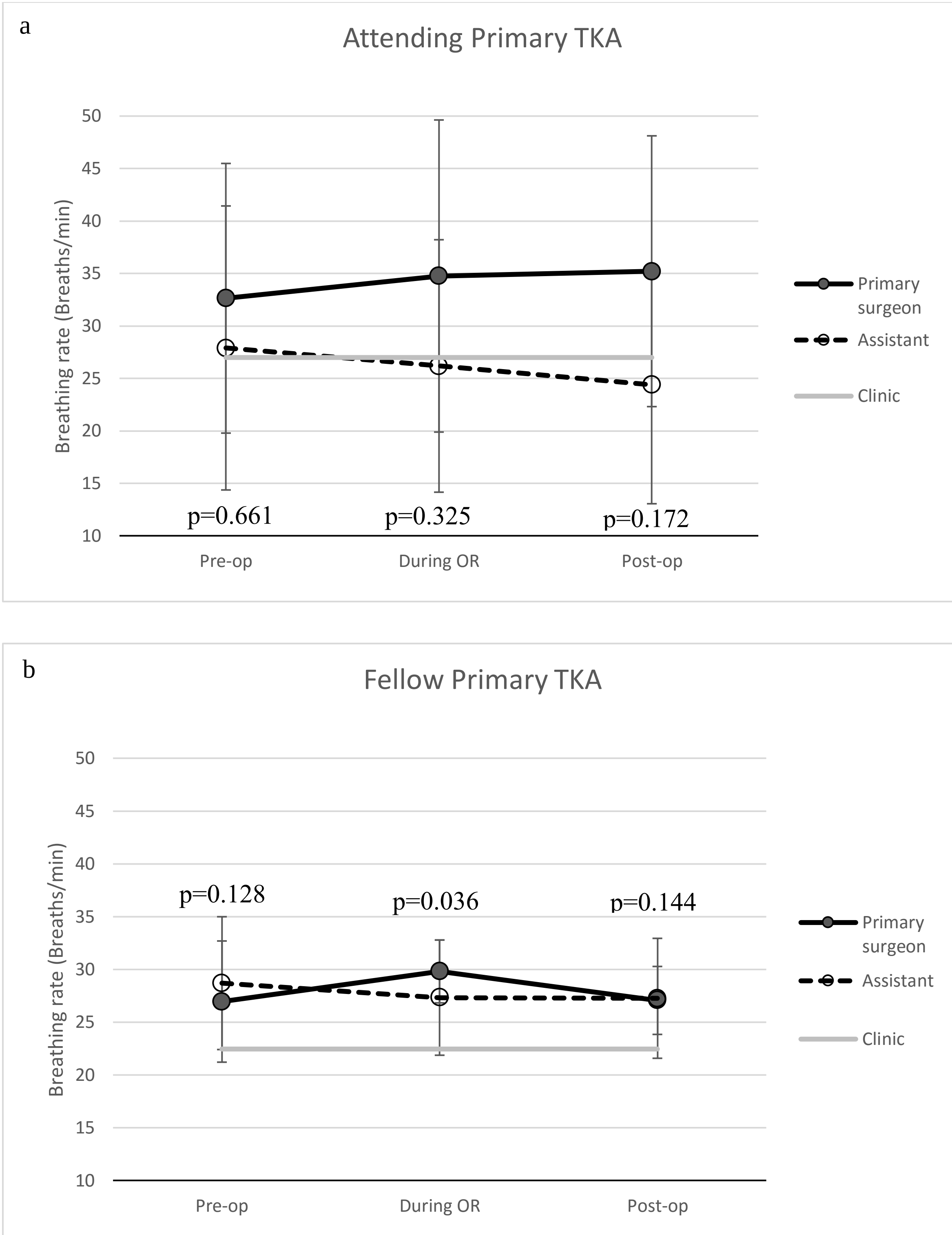
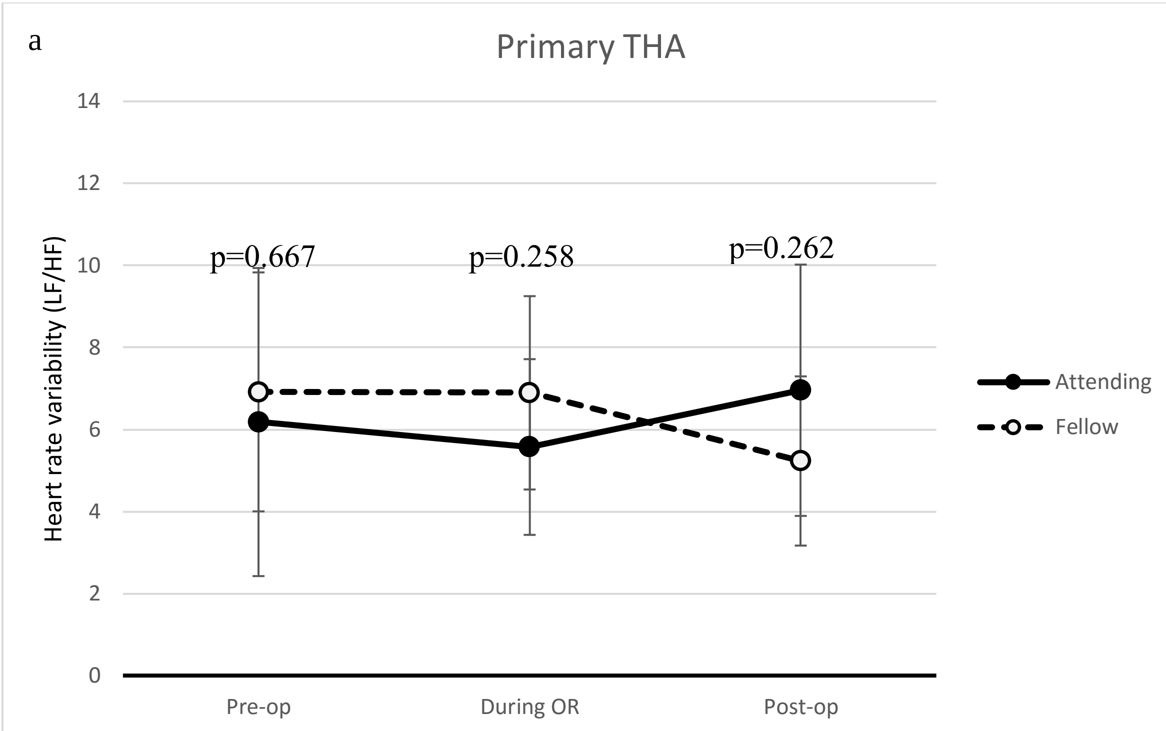


Figure 3-5 Breathing rate during total knee arthroplasty by a) Staff and b) Clinical fellows

Heart rate variability (HRV) comparison between staff and fellows, independent of surgical roles, is shown in Figure 3-6. Overall, there was no difference noted in the variability between staff and fellows at any moment around and during THA when combining all data collected. On the contrary, fellows had significantly higher variability during TKA and maintained this increased variability in the postoperative period.

Analysis of the HRV results dependent on the role performed (surgeon or primary assistant) by staff and fellows during primary THA and primary TKA are shown in Figure 3-7 and 3-8 respectively. In THA, staff failed to show any statistical difference between the HRV in the cases they were assuming the role of primary surgeon compared to the cases they were assisting and the clinic days. On the other hand, fellows showed significantly higher HRV when they were assisting during THA compared to when they were assuming the primary surgeon role or during their clinic days. In the preoperative period prior to THA, post-hoc analysis did not show increased variability in the assistant role compared to clinic day ($p=0.067$). No statistical difference was noted between the different roles assumed in the preoperative period. In TKA, staff also failed to show any statistical difference between the HRV throughout the data collection period regardless of the role assumed and the clinic days. Fellows showed no significant difference between the roles during TKA.



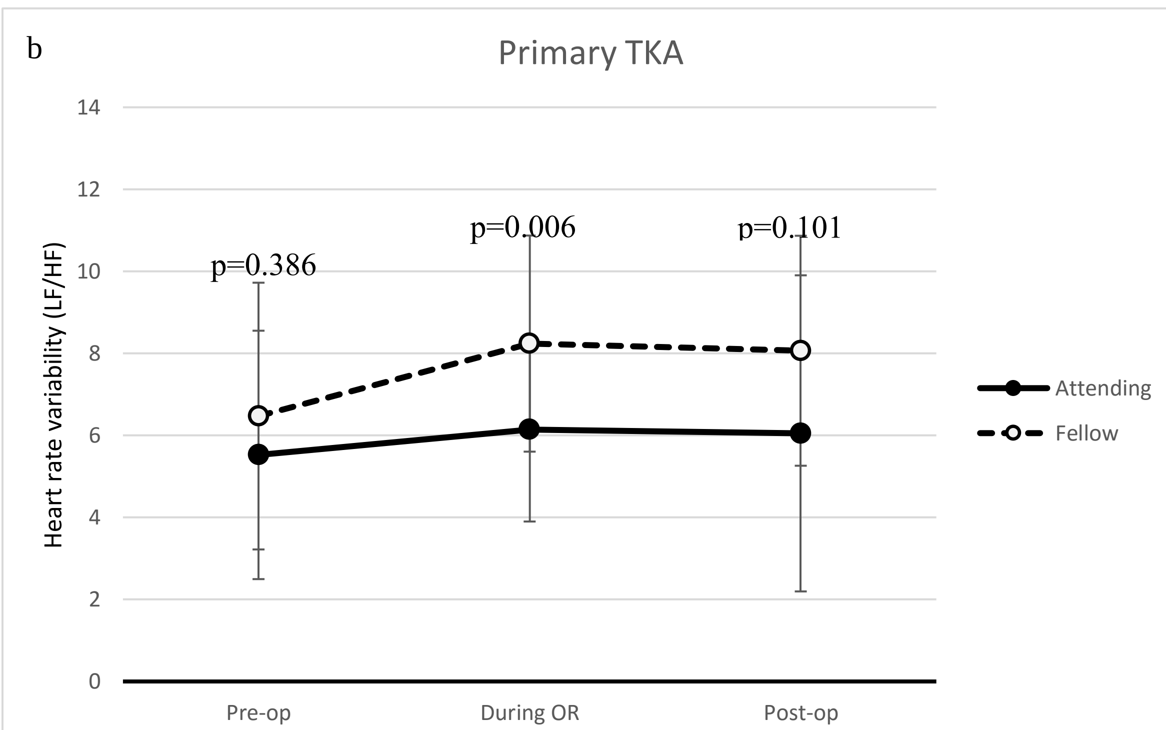


Figure 3-6 Heart rate variability regardless of role occupied during a) total hip arthroplasty and b) total knee arthroplasty

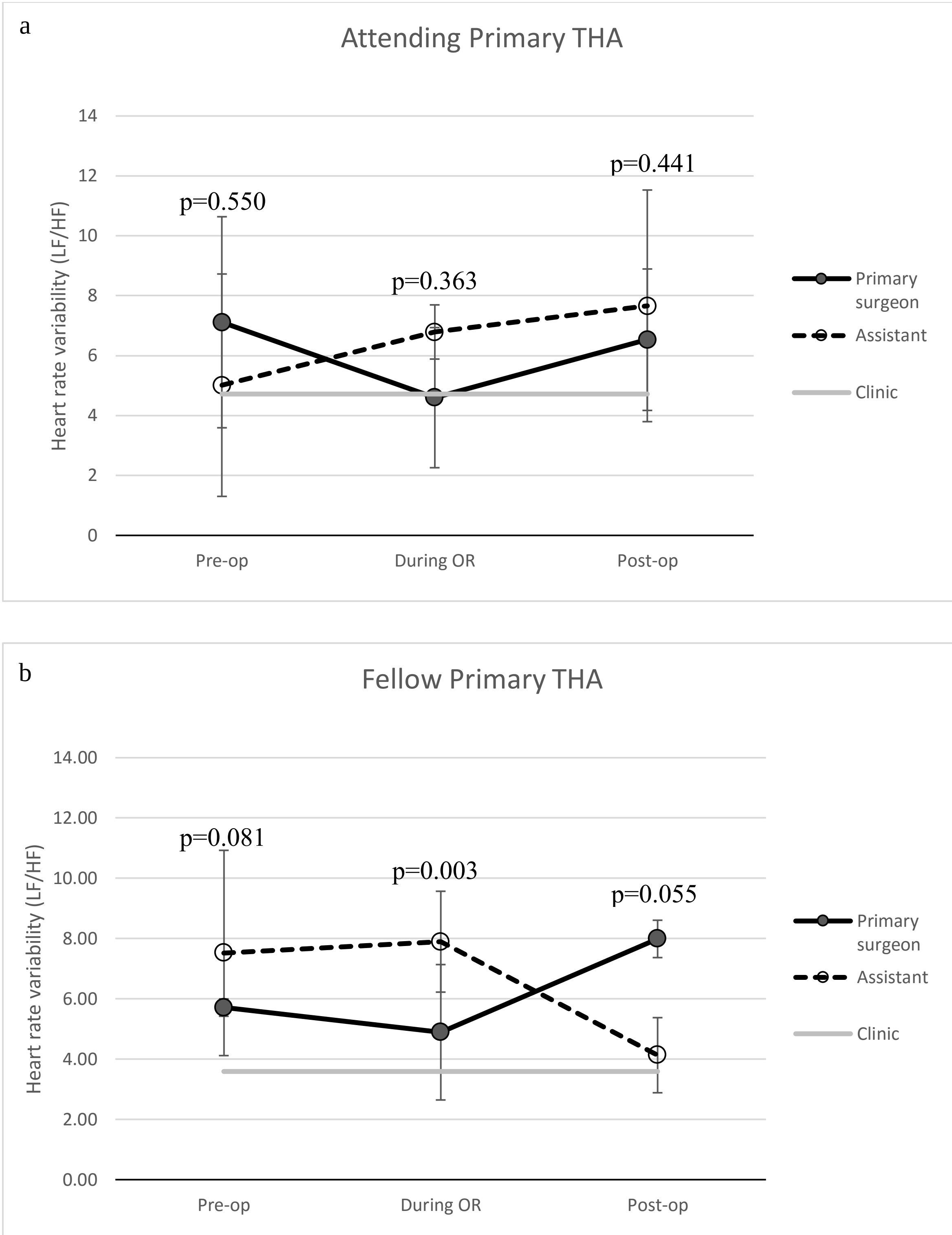
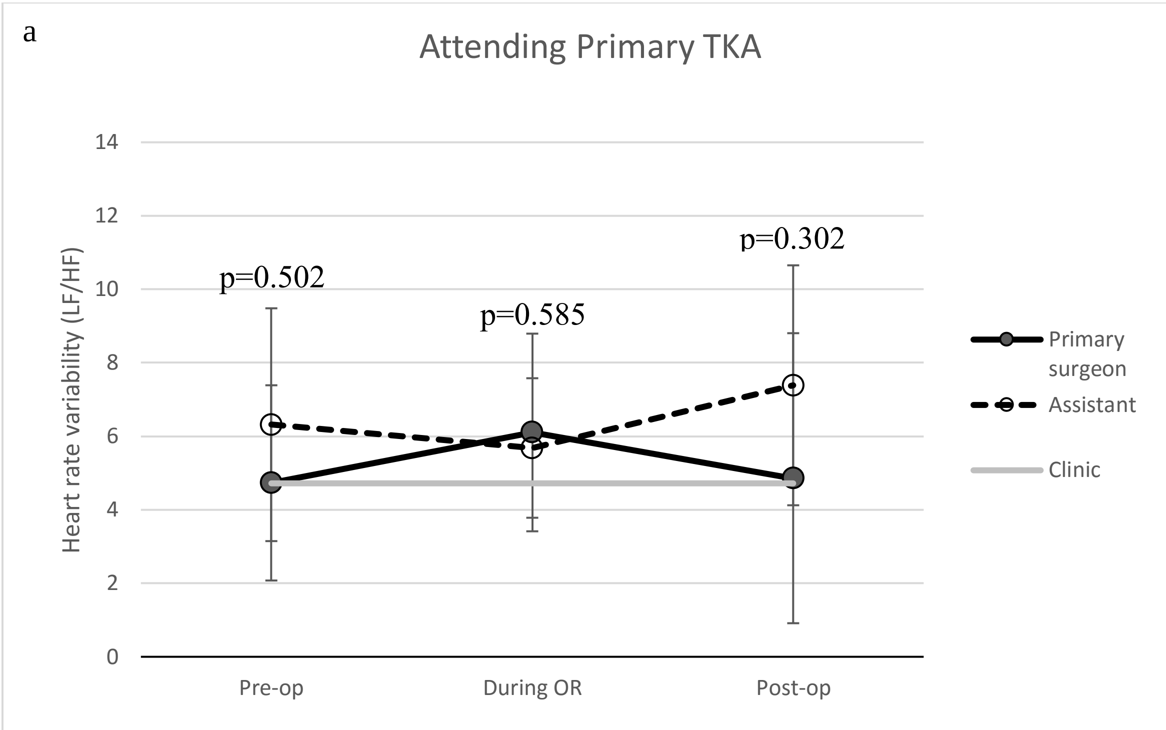


Figure 3-7 Heart rate variability during total hip arthroplasty by a) Staff and b) Clinical fellows



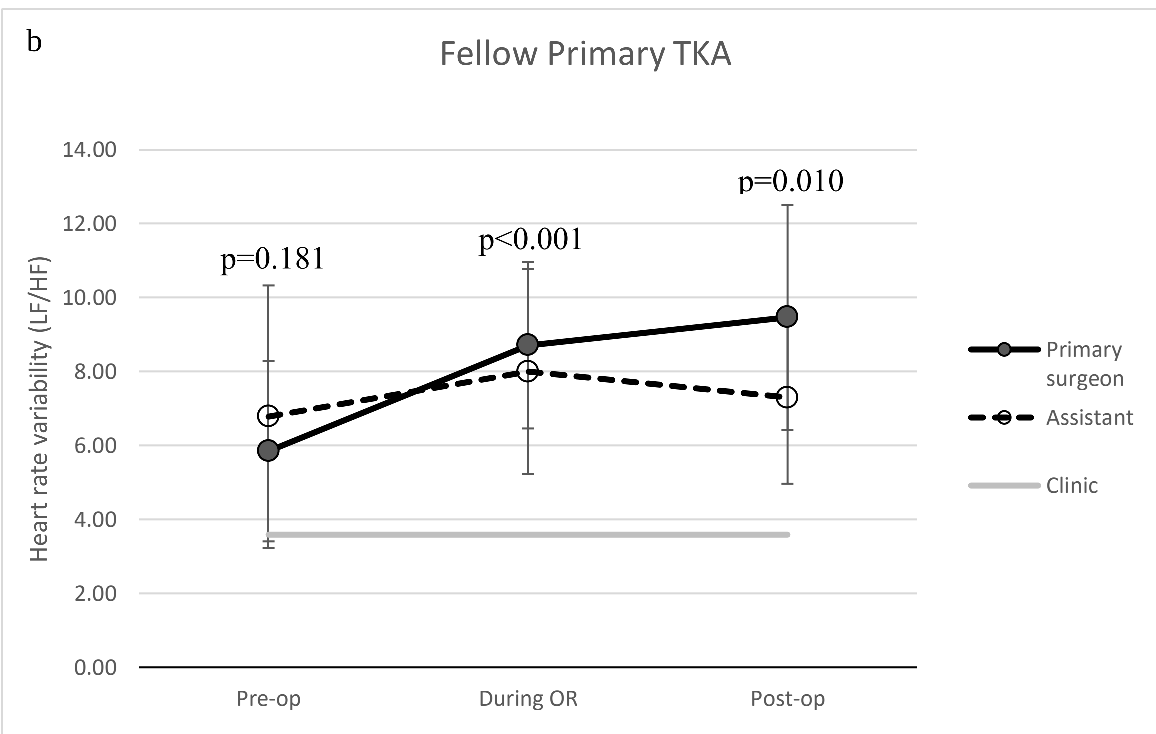


Figure 3-8 Heart rate variability during total knee arthroplasty by a) Staff and b) Clinical fellows

STAI questionnaires did not show any difference between staff and fellows in both the preoperative and postoperative period (Table 3-1). There was no correlation noted between the STAI scores and physiological responses like HRV (R^2=-0.136).

Table 3-1 STAI questionnaire score

	Staff	Fellow	p-value
Pre-op	45.4	46.2	0.216
Post-op	45.7	45.3	0.582
p-value	0.604	0.145	-

3.4 Discussion

The aim of this study was to track physiological and psychological responses to common hip and knee surgeries, as well as during clinic in a cohort of surgeons and their fellows. This study is the first to our knowledge involving common orthopaedic surgery procedures and physiological responses, since only questionnaire-based studies have been done in this field[9]. It is logical to state that some of the common orthopaedic surgical procedures are unique since they involve an added degree of physical effort compared to other surgeries such as general surgery. The physicality of these surgeries adds to the physiological responses experienced by the surgeon to the stressors surrounding the surgery itself. This makes it even more important to use HRV as our measurement tool to perform such analyses.

Physiological responses tended to be different between the staff and the fellows regardless of the procedures performed. Specifically, fellows had overall a higher HR in the role of primary surgeon while the staff showed no difference in HR regardless of the role assumed. Similarly, staff seemed to maintain no significant differences between their breathing rate in the OR compare to the clinic days while fellows showed a tendency towards increased respiratory rate during OR days compare to clinic days, especially during TKA where the difference reached statistical significance. Moreover, staff maintained a HRV similar between OR days and clinic days compared to fellows who showed higher variability during OR days compared to clinic days. Interestingly, fellows had higher variability while assisting in THA, while there was no difference noted between roles during TKA.

Multiple factors could potentially explain such results. First, the staff are more experienced in the type of cases that were performed in the study compared to the clinical fellows. Second, there might be a difference in the complexity of cases that each group had. Fellows might be assigned from their staff to perform more complex type of primary THA and TKA for an education purpose. Third, fellows have the extra task of learning the habits of each staff separately which might be accentuating the stress experienced by the fellows. Unfortunately, the data obtained do not permit the analysis of differences in physiological responses between early rotation cases and late rotation cases for the fellows. Future larger studies will help to further explore this issue.

Intensity noted during the cases for each role and during clinic days from staff and fellows were not different and followed similar patterns to HR changes, however this was different than what was observed with HRV. This accentuates the importance of the HRV analysis for our study since HR changes seemed more affected by the intensity of the procedure itself.

Data collected from the STAI questionnaire did not show any correlation with the physiological parameters that were collected. This questionnaire is a validated questionnaire that has previously been used to evaluate stress levels in surgeons. However, some of the results obtained from those questionnaires could be affected by the acute repetition of data with the high number of questionnaires that the participants had to fill during a single day. Moreover, some questions present in that form might be interpret by the participant in a way that would lead them to answer the question in a way that adds some bias in the collection of results (i.e. A surgeon would not feel comfortable to admit that he “feels indecisive” just before starting a procedure). Therefore, it might influence the results obtained.

There are some limitations to this study. First, noise in the EKG tracing collected might have interfered with the results obtained. We anticipate this effect would be small as the Vivosense software uses automatic filters to diminish the effect of the noise on the collected data as much as possible. Second, as mentioned above, STAI questionnaire results might be influenced by different factors making those results less interpretable.

Third, the results might have been blunted by the fact that the trainees evaluated during this study were certified orthopaedic surgeons undergoing extra training for those common orthopaedic procedures. Fourth, the sample of staff and fellows were selected within a single institution, therefore limiting the number of participants and in the same way the statistical power of the study. Lastly, given the stress test was not performed at the beginning of the study but rather at any point during the period where data was collected. Nevertheless, since there was no planned exercise program for the participants in the study, there is very little change expected in maximal exercise capacity over a year as it has been previously shown in other studies and maximal heart rate is better predicted by age[11]. Therefore, timing of the baseline stress test is not expected to have any effect on our results.

Overall, this study represents a first step in the evaluation of physiological changes during common orthopaedic surgery procedures by both staff and fellows involved in those surgeries. Since we are able to show that these procedures can be more stressful for the trainees, this could be used as a basis to expand this type of analysis by evaluating the different steps involved in a procedure, and evaluating specific events that could represent stressors for the trainees. The study could also expand to trainees with less experience including junior year residents. Implementation of the new models of surgical training which are competency-based, it will become increasingly important to improve the learning environment.

3.5 Conclusion

In conclusion, this study is the first study evaluating the physiological and psychological changes experienced by a cohort of orthopaedic surgeon and their trainees. Different stress patterns were noted in clinical fellows compared to the staff, especially showing a higher overall HRV during TKA. Further investigation to evaluate and identify specific steps intraoperatively which constitute stressors, identify their effect on learning and practice, and to provide interventions to optimize the environment for both the surgeon as well as other members of the health care provider team and trainees is required. Moreover, further investigation should expand to include orthopaedic surgery residents and medical students in addition to the clinical fellows.

3.6 References

1. Arora S, Aggarwal R, Moran A, Sirimanna P, Crochet P, Darzi A, et al. Mental practice: effective stress management training for novice surgeons. J Am Coll Surg. 2011;212(2):225-33.

2. Bautmans I, Gorus E, Njemini R, Mets T. Handgrip performance in relation to self-perceived fatigue, physical functioning and circulating IL-6 in elderly persons without inflammation. BMC Geriatr. 2007;7:5.

3. Cecil J, McHale C, Hart J, Laidlaw A. Behaviour and burnout in medical students. Med Educ Online. 2014;19:25209.

4. Eisenach JH, Sprung J, Clark MM, Shanafelt TD, Johnson BD, Kruse TN, et al. The psychological and physiological effects of acute occupational stress in new anesthesiology residents: a pilot trial. Anesthesiology. 2014;121(4):878-93.

5. Flinn JT, Miller A, Pyatka N, Brewer J, Schneider T, Cao CG. The effect of stress on learning in surgical skill acquisition. Med Teach. 2015:1-7.

6. Hernández-Gaytan SI, Rothenberg SJ, Landsbergis P, Becerril LC, De León-León G, Collins SM, et al. Job strain and heart rate variability in resident physicians within a general hospital. Am J Ind Med. 2013;56(1):38-48.

7. Kuhn EW, Choi YH, Schönherr M, Liakopoulos OJ, Rahmanian PB, Choi CY, et al. Intraoperative stress in cardiac surgery: attendings versus residents. J Surg Res. 2013;182(2):e43-9.

8. Mata DA, Ramos MA, Bansal N, Khan R, Guille C, Di Angelantonio E, et al. Prevalence of Depression and Depressive Symptoms Among Resident Physicians: A Systematic Review and Meta-analysis. JAMA. 2015;314(22):2373-83.

9. Morales J, Alamo JM, García-Massó X, Buscà B, López JL, Serra-Añó P, et al. Use of heart rate variability in monitoring stress and recovery in judo athletes. J Strength Cond Res. 2014;28(7):1896-905.

10. Mota MC, De-Souza DA, Rossato LT, Silva CM, Araújo MB, Tufik S, et al. Dietary patterns, metabolic markers and subjective sleep measures in resident physicians. Chronobiol Int. 2013;30(8):1032-41.

11. Pohjonen T, Ranta R. Effects of worksite physical exercise intervention on physical fitness, perceived health status, and work ability among home care workers: five-year follow-up. Prev Med. 2001;32(6):465-75.

12. Sargent MC, Sotile W, Sotile MO, Rubash H, Barrack RL. Quality of life during orthopaedic training and academic practice. Part 1: orthopaedic surgery residents and faculty. J Bone Joint Surg Am. 2009;91(10):2395-405.

13. Song MH, Tokuda Y, Nakayama T, Sato M, Hattori K. Intraoperative heart rate variability of a cardiac surgeon himself in coronary artery bypass grafting surgery. Interact Cardiovasc Thorac Surg. 2009;8(6):639-41.

14. Thomas C, Power C. Shift work and risk factors for cardiovascular disease: a study at age 45 years in the 1958 British birth cohort. Eur J Epidemiol. 2010;25(5):305-14.

15. Vrijkotte TG, van Doornen LJ, de Geus EJ. Effects of work stress on ambulatory blood pressure, heart rate, and heart rate variability. Hypertension. 2000;35(4):880-6.

16. Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. CMAJ. 2006;174(6):801-9.

17. West CP, Huschka MM, Novotny PJ, Sloan JA, Kolars JC, Habermann TM, et al. Association of perceived medical errors with resident distress and empathy: a prospective longitudinal study. JAMA. 2006;296(9):1071-8.

18. Zhong X, Xiao Y, Huang R, Huang XZ. [The effects of overnight sleep deprivation on cardiovascular autonomic modulation]. Zhonghua Nei Ke Za Zhi. 2005;44(8):577-80.

Chapter 4

4 Comparison of physiological responses during lateral and anterior approach total hip arthroplasty

4.1 Introduction

Total hip arthroplasty (THA) represents one of the most successful surgeries, with 95% success rate to relieve pain and recover normal function[6]. Despite the success of this procedure, research is being done in order to improve the instrumentation, implants, and technique and, therefore, its outcome. One field of interest in research for total hip arthroplasty includes the comparison between surgical approaches. Traditionally, the most common approaches used included the posterolateral approach popularized by Dr Moore in the 1960s and the direct lateral approach popularized by Hardinge in the 1980's[3]. In the last few years, a direct anterior muscle-sparing approach has gained popularity in total hip arthroplasty using the internervous plane between Sartorius muscle and Tensor fascia lata muscle to access the hip joint[1]. A recent review of the surgical techniques for each approach and reviewing the literature comparing these approaches has been done[9].

Despite the theoretical advantage of the direct anterior approach, it makes the procedure more technically challenging. It has been shown in multiple studies that the learning curve for the surgeons using this approach is challenging[2,4-5,10]. Therefore, we could potentially extrapolate that teaching the residents and clinical fellows this surgical technique is more difficult than other approaches, and that surgeons planning to begin this procedure need to invest greater effort and time to acquire the skills required before adopting this as their preferred approach.

The medical trainees are already exposed to a substantial amount of stress and a resulting high percentage of depression or depressive symptoms can be found amongst them[7]. As our medical educational system moves towards competency-based training, it becomes important to identify and minimize the elements contributing to those high stress levels and psychological issues. The purpose of this study is to evaluate the physiological changes noted in staff and trainees during THA and compare the changes during lateral approach cases and anterior approach cases. Our hypothesis is that the physiological and psychological responses noted by both staff and fellows during anterior approach THA would be more significant than during lateral approach THA.

4.2 Material and methods

Consent was obtained from the adult hip and knee reconstruction specialized surgeons and the clinical fellows training in a single institution from July 2015 to June 2016, and the participant was fully informed about the methods to be used throughout the study. Participant that had cardiovascular medical comorbidities or under treatment influencing the monitoring were excluded from the study as well as participants that were unable to wear the monitors or that had a BMI lower than 18 or higher than 35. Data was collected by an independent research assistant. Institutional human research ethics clearance was obtained for this study.

The protocol used was similar to the protocol described in chapter 3. Data was collected from a baseline stress test that each participant underwent at the beginning of the study. Thereafter, monitoring of the participants was done using Equivital EQO2 HRV holter monitor (Vivonoetics, San Diego, California) during the different procedures as well as in clinic. Approach used (either direct lateral or direct anterior approach) was noted.

The data collected from the monitoring included heart rate (HR), respiratory rate and heart rate variability (HRV). Data was also collected through STAI questionnaires preoperatively and postoperatively. The data between surgical approaches as well as data between staff and fellows for each approach was compared using T-test to identify for differences in the mean levels recorded. T-test was also used to compare data collected through STAI questionnaires.

4.3 Results

A total of three joint reconstruction orthopaedic surgeons working in a single academic institution and five orthopaedic surgery clinical fellows training in the same institution from July 2015 to June 2016 were included in the study. One surgeon was performing only lateral approach THA, One surgeon was performing only anterior approach THA and one surgeon was selectively performing either approach. None of the potential participants were excluded from the study. Data from baseline stress test was collected from all the participants. Data was recorded from eleven total hip arthroplasty (THA), six using the lateral approach and five using the anterior approach.

A comparison of data between lateral approach and anterior approach cases for staff and clinical fellows are shown in figures 4-1 and 4-2 respectively as well as in Table 4-1. For the staff, although there was no significant difference noted in HR, %HRmax and breathing rate between the different approaches, there was a significantly increased HRV while performing lateral approach compared to anterior approach (p=0.008). For the fellows, significant increased HR was noted in lateral approach THA (p=0.030). No significant difference was noted in breathing rate between the different approaches. There was also no difference in HRV during anterior THA compared to lateral approach (p=0.193).

Table 4-1 Comparison of procedure intensity (%HRmax)

	Staff	Fellow	p-value
Anterior	73.5	62.1	0.301
Lateral	58.9	80.2	0.202
p-value	0.264	0.236	-

A comparison of data between staff and fellows for lateral and anterior approaches are shown in figures 4-3 and 4-4 respectively as well as table 4-1. For lateral approach THA, there was no significant difference between all the physiological parameters evaluated

(HR, breathing rate, HRV) of staff and fellows. Regarding anterior approach THA, the situation was different. HR was significantly higher for staff compared to the fellows during anterior THA (p=0.041). Breathing rate was not significantly different between staff and fellow intraoperatively or preoperatively, but fellows did have higher breathing rates in the postoperative period (p=0.036). HRV was significantly higher for fellows compared to staff during anterior THA (p=0.006).

STAI questionnaires did not show any difference between staff and fellows in both preoperative and postoperative periods in lateral and anterior approach (Table 4-2, 4-3).

Table 4-2 STAI questionnaire score lateral approach

	Staff	Fellow	p-value
Pre-op	45.8	50.5	0.187
Post-op	47	47	1.000
p-value	0.407	0.258	-

Table 4-3 STAI questionnaire score anterior approach

	Staff	Fellow	p-value
Pre-op	47	45	0.626
Post-op	45	47	0.626
p-value	0.626	0.626	-

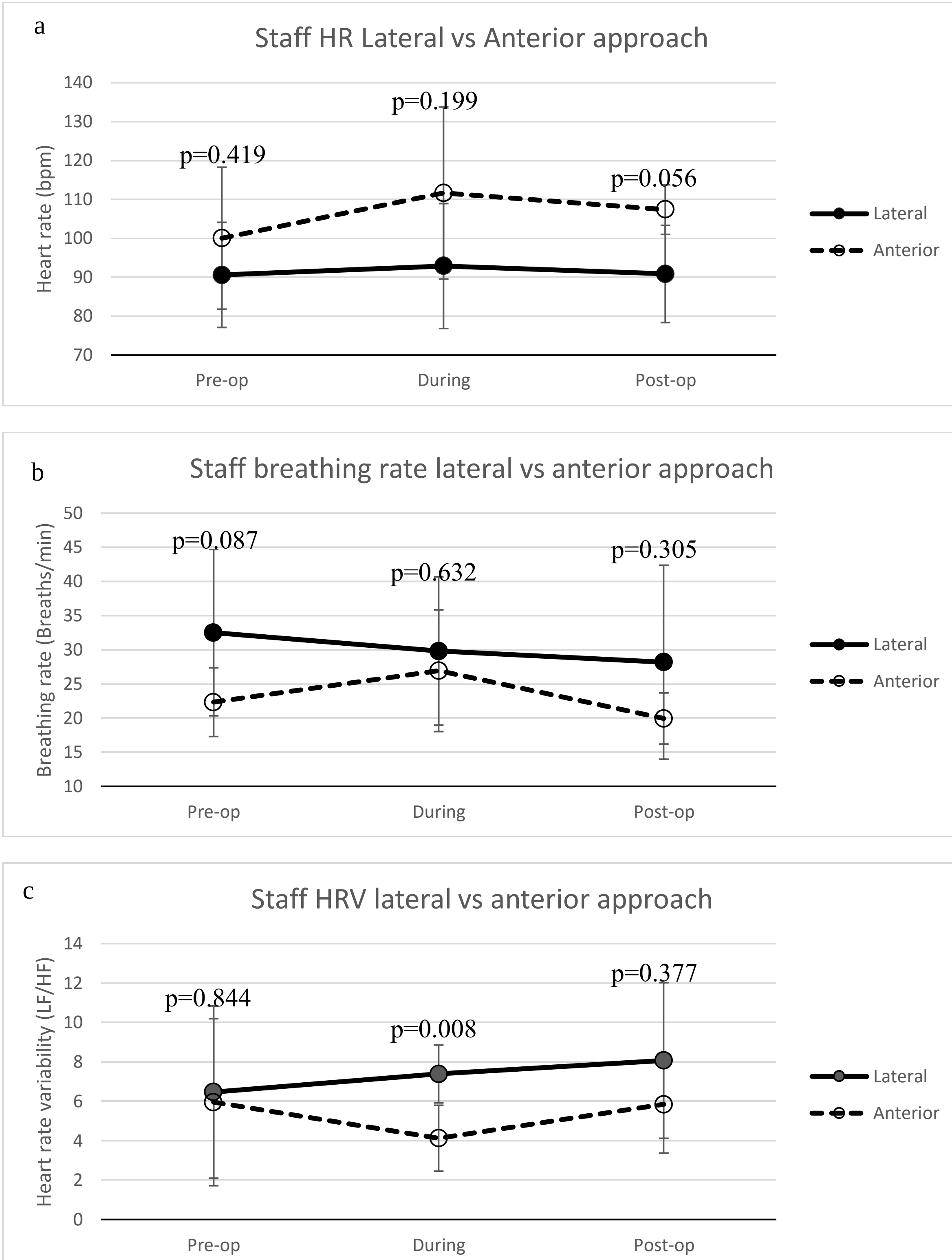


Figure 4-1 Comparison of staffs' physiological responses (a-Heart rate, b-Breathing rate, c-Heart rate variability) between different approaches

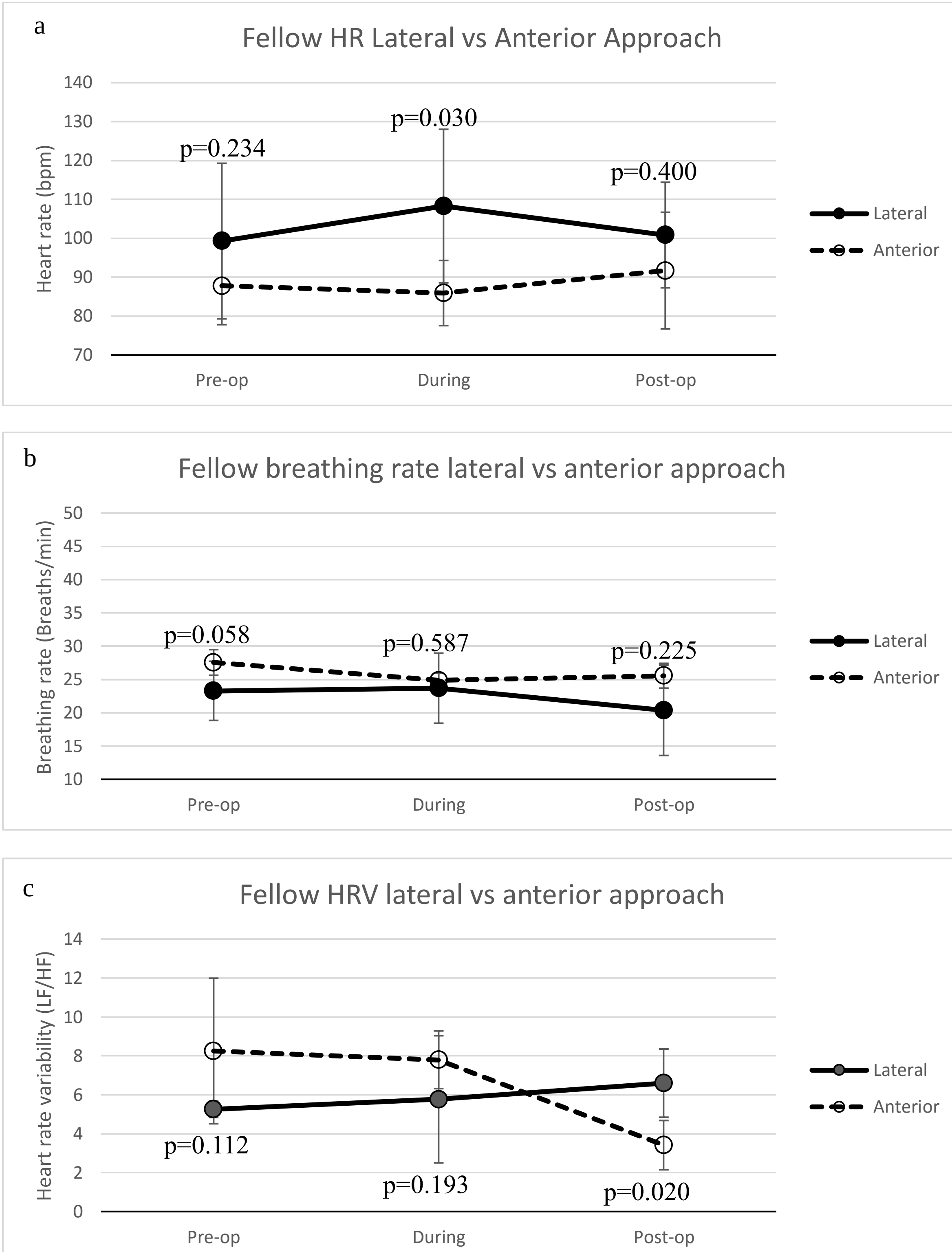


Figure 4-2 Comparison of fellows' physiological responses (a-Heart rate, b-Breathing rate, c-Heart rate variability) between different approaches

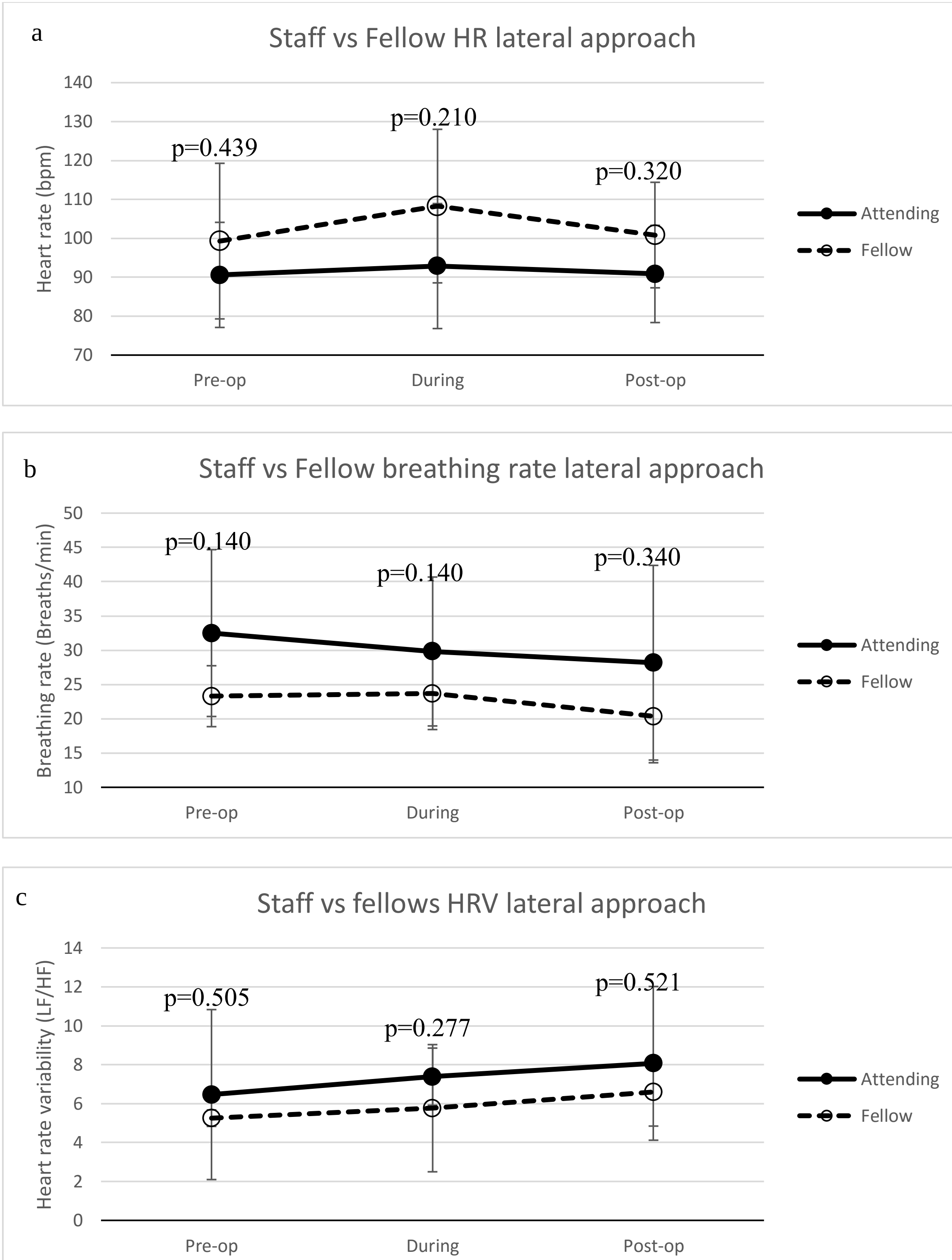


Figure 4-3 Physiological responses (a-Heart rate, b-Respiratory rate, c-Heart rate variability) of staff and fellows during lateral approach THA

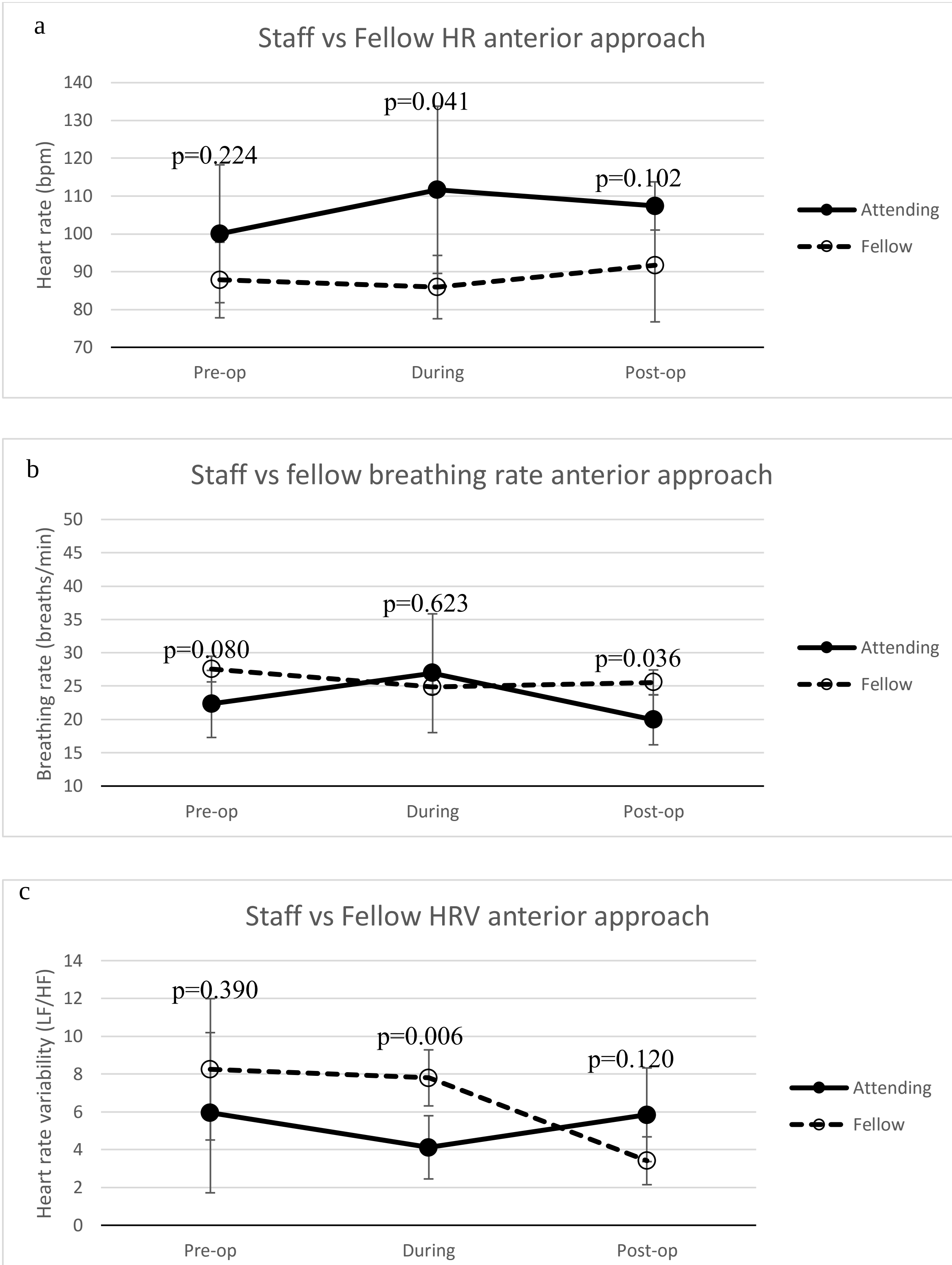


Figure 4-4 Physiological responses (a-Heart rate, b-Respiratory rate, c-Heart rate variability) of staff and fellows during anterior approach THA

4.4 Discussion

The aim of this study was to compare physiological and psychological responses to different approaches used for THA in a cohort of orthopaedic surgeons and their clinical fellows. This study is the first that examined how different techniques for a single surgical procedure affected the surgeon.

The consultant surgeons had some interesting findings shown above. They showed overall lower HRV performing a direct anterior than during a lateral THA. This is contrary to what was expected since, as discussed above, anterior THA is considered more technically demanding and has a long learning curve[8]. We hypothesize that those results might be affected by the fact that there was a selection bias probably introduced during the data collection. The staff who were performing both type of approaches selected in a non-blind fashion cases that were suitable to undergo anterior approach THA. Therefore, the profile of patient undergoing lateral approach THA was different from the ones undergoing anterior THA. The more complicated patients with higher BMIs were more likely in the lateral approach group. This case selection reflected somewhat of an effect onto the fellows as well, which did not show any significant difference in HRV between lateral and anterior THA. There may also be the presence of a protective effect of the learning environment for trainees performing new procedures.

Second, when evaluating the reaction of staff and fellows to the anterior THA, we note an increased variability in fellows compared to staff. This is in agreement with what was expected prior to the study. Although the learning environment of the trainees seemed well protected by the staff, anterior approach total hip arthroplasty represents a new technique for them. Staff having been already through their learning curve have less stress going through those cases compare to the fellows who were still at the beginning of their learning curve.

There are some limitations to this study. First, noise in the EKG tracing collected might have interfered with the results obtained. We anticipate this effect would be small as the Vivosense software uses automatic filters to diminish the effect of the noise on the collected data as much as possible. Second, as mentioned above, there might be a selection bias between the type of cases that were made through an anterior approach compared to the ones made through a lateral approach. Although this could have given us some information regarding the training environment, it did not permit a complete picture of the difference between the physiological responses in both approaches. Moreover, we obtained data from a single –institution limited the amount of data we could obtained and also might mean that the data could not be generalized. However, having more than one surgeon involved in the study might make this data generalized to the population. A multicenter randomized-controlled study were patients would be matched and randomized to either approach for all surgeons involved in the study would further allow a clearer understanding and a better generalization of the results. Finally, each surgeon separately as well as each trainee was not in the same stage of their learning curve for anterior approach THA, therefore the results might have been blunted. Indeed, one of the staff was within the first year he introduced this approach to his practice while the other surgeon was using for the most part this approach for at least four years before the study. Similarly, two of the fellows had trained during residency using the anterior approach THA as the primary surgical approach.

Overall, this study represents an evaluation of physiological changes during different approaches in THA surgery. This study could be expanded by evaluating the different steps involved into each type of THA and evaluating specific events that could represent stressors for both the staff and trainees. The study could also expand to trainees with less experience including junior year residents. As surgical training begins to adopt components of competency-based models, it will become increasingly important to improve the learning environment. Moreover, such study would potentially permit a greater understanding of intraoperative stressors in order to make the procedure more predictable, and therefore diminish the learning curve for more technically demanding procedure like the anterior approach THA.

4.5 Conclusion

In conclusion, this study is the first study comparing the physiological and psychological changes experienced by a cohort of orthopaedic surgeon and their trainees during different approaches THA. Fellows experience more stress during anterior THA, although staff can influence the stress levels partially by selecting the cases appropriately. Further investigation to evaluate and identify specific steps intraoperatively which constitute stressors and identify their effect on learning and practice is required to potentiate interventions to improve learning. Moreover, further investigation should be expanded to include orthopaedic surgery residents and medical students in addition to the clinical fellows.

4.6 References

1. Berry DJ, Lieberman JR. Surgery of the hip. Philadelphia, PA: Elsevier/Saunders; 2013. xxvi, 1321 p. p.

2. Bhandari M, Matta JM, Dodgin D, Clark C, Kregor P, Bradley G, et al. Outcomes following the single-incision anterior approach to total hip arthroplasty: a multicenter observational study. Orthop Clin North Am. 2009;40(3):329-42.

3. Canale ST, Beaty JH, Campbell WC. Campbell's operative orthopaedics. 12th ed. St. Louis, Mo.: Elsevier/Mosby; 2013.

4. de Steiger RN, Lorimer M, Solomon M. What is the learning curve for the anterior approach for total hip arthroplasty? Clin Orthop Relat Res. 2015;473(12):3860-6.

5. Goytia RN, Jones LC, Hungerford MW. Learning curve for the anterior approach total hip arthroplasty. J Surg Orthop Adv. 2012;21(2):78-83.

6. Malchau H, Herberts P. Prognosis of total hip replacement. Int J Risk Saf Med. 1996;8(1):27-45.

7. Mata DA, Ramos MA, Bansal N, Khan R, Guille C, Di Angelantonio E, et al. Prevalence of Depression and Depressive Symptoms Among Resident Physicians: A Systematic Review and Meta-analysis. JAMA. 2015;314(22):2373-83.

8. Moskal JT, Capps SG, Scanelli JA. Anterior muscle sparing approach for total hip arthroplasty. World J Orthop. 2013;4(1):12-8.

9. Petis S, Howard JL, Lanting BL, Vasarhelyi EM. Surgical approach in primary total hip arthroplasty: anatomy, technique and clinical outcomes. Can J Surg. 2015;58(2):128-39.

10. Seng BE, Berend KR, Ajluni AF, Lombardi AV. Anterior-supine minimally invasive total hip arthroplasty: defining the learning curve. Orthop Clin North Am. 2009;40(3):343-50.

Chapter 5

5 General discussion and conclusion

5.1 General discussion

Surgeons are exposed to high levels of stress during their practice, leading to high levels of mental exhaustion and depression amongst them[12]. Medical training involves a combination of clinical duties and the acquisition of knowledge and skills. This can be overwhelming for trainees, who have also been shown to have with high rates of depression[8]. Multiple changes have been attempted to identify those stressors[2,4-5,15] and to find solutions to improve the learning environment[7,9,11,13,16]. Most of those studies were questionnaire-based and, therefore, evaluating mainly the cognitive aspect of the experienced stress via subjective data. The physical aspect of stress was only rarely evaluated in those studies. In other domains like in sports, heart rate variability has already been used for years to evaluate physical stress experienced during training and competition in order to optimize overall performance[10]. Only limited number of studies have used this type of evaluation in the medical field[1,3,6,14], but it has never been used in orthopaedic surgery to our knowledge. The goal of this study was to evaluate the physiological changes noted in orthopaedic surgeons, compare them to the changes noted in their trainees, and correlate those findings with psychological assessment during their clinical duties.

Given these type of procedures involves a high level of physical activity compared to other surgical interventions, we first evaluated the feasibility of such study. In our pilot study, we noted that the heart rate variability was higher in more complicated cases. Moreover, the variability was increased throughout the surgical days compare to the clinic days. All those results were expected given a more technically demanding procedure would involve a higher level of stress for the individual performing it. Although there was no correlation noted with the results from the psychological evaluation through the STAI questionnaire, this pilot study showed that the equipment used was feasible to measure physiologic responses as a marker of stress in orthopaedic surgery procedures.

We then proceeded in the main part of the study. We first did an evaluation of the different changes noted during THA and TKA and evaluated how the different roles assumed by the staff and fellows would affect the stress levels. As expected, fellows presented different stress pattern than staff. For the staff, clinic work or OR did not show to affect HRV. However, other physiological parameters were increased during OR days, which was related to the physicality of the procedures. On the other hand, fellows clearly had higher variability during OR compared to clinic. This study also demonstrated that HRV was a better evaluation tool than HR alone for the purpose of identifying stress levels, since HR was more closely influenced by the intensity of the procedure than HRV.

We then decided to evaluate how the complexity of a similar procedure could affect the stress levels. We chose to compare the physiological changes noted during two different approaches used to perform a THA; the direct lateral and the direct anterior approach. No major difference was noted for the fellows between the surgical approaches used. For the staff, a higher variability was noted during lateral approach THA. Those results were opposite to what we were expecting given the anterior approach THA is considered more technically demanding. However, given there was a non-controlled selection of cases that would undergo each approach, we suspected that there might have been a selection bias putting easier type cases to undergo THA through anterior approach. The nurturing learning environment of the fellows may also dampen the stress the fellows experience.

5.2 Strengths and limitations of the study

This study is the first which attempts to evaluate the physiological changes noted during orthopaedic surgery and correlate it with psychological questionnaire results. This is an important step in better understanding how the staff and trainees are reacting to different type of common orthopaedic procedures. It will be the basis for further studies in this domain. The design of the study also helps provide further evidence that HR alone is not a good evaluation tool for stress since it is influenced by the intensity of the procedure performed, therefore advocating for the use of HRV as a more precise tool in this matter.

There are also some limitations to the study. First, given the nature of the study, there might have been a selection bias in the cases present in the different groups evaluated. A randomized-controlled trial matching the cases that are present in each group might permit to diminish this effect

Second, the trainees chosen during this study were already certified orthopaedic surgeons who were training in the institution under the supervision of the staff involved to specialize in those type of procedures. Therefore, they already had some experience with those procedures. Expanding the study including medical residents in both junior and senior years as well as medical student might be giving different results.

Third, the design of the study did not permit to identify specific steps that could contribute to the elevated stress in each procedure. Further study could possibly record responses to each surgical step for a more precise understanding.

5.3 Conclusion

In conclusion, this study is the first one of this type evaluating physiological and psychological responses of staff and fellows in common orthopaedic surgery procedures. Based on our study, we were able to identify which procedures could represent higher stress for both groups. For instance, a higher variability was noted during TKA overall for the clinical fellows. Future studies in this field could expand to other level trainees as well as breaking down of each type of procedure into its different steps to target the more stressful aspects of each surgery.

5.4 References

1. Andreatta PB, Hillard M, Krain LP. The impact of stress factors in simulation-based laparoscopic training. Surgery. 2010;147(5):631-9.

2. Cecil J, McHale C, Hart J, Laidlaw A. Behaviour and burnout in medical students. Med Educ Online. 2014;19:25209.

3. Eisenach JH, Sprung J, Clark MM, Shanafelt TD, Johnson BD, Kruse TN, et al. The psychological and physiological effects of acute occupational stress in new anesthesiology residents: a pilot trial. Anesthesiology. 2014;121(4):878-93.

4. Gardiner P, Filippelli AC, Lebensohn P, Bonakdar R. The incorporation of stress management programming into family medicine residencies-results of a national survey of residency directors: a CERA study. Fam Med. 2015;47(4):272-8.

5. Goldhagen BE, Kingsolver K, Stinnett SS, Rosdahl JA. Stress and burnout in residents: impact of mindfulness-based resilience training. Adv Med Educ Pract. 2015;6:525-32.

6. Harvey A, Bandiera G, Nathens AB, LeBlanc VR. Impact of stress on resident performance in simulated trauma scenarios. J Trauma Acute Care Surg. 2012;72(2):497-503.

7. Malik M, Camm AJ. Dynamic electrocardiography. Oxford: Blackwell Futura; 2004.

8. Mata DA, Ramos MA, Bansal N, Khan R, Guille C, Di Angelantonio E, et al. Prevalence of Depression and Depressive Symptoms Among Resident Physicians: A Systematic Review and Meta-analysis. JAMA. 2015;314(22):2373-83.

9. Morrow G, Burford B, Carter M, Illing J. Have restricted working hours reduced junior doctors' experience of fatigue? A focus group and telephone interview study. BMJ Open. 2014;4(3):e004222.

10. Plews DJ, Laursen PB, Stanley J, Kilding AE, Buchheit M. Training adaptation and heart rate variability in elite endurance athletes: opening the door to effective monitoring. Sports Med. 2013;43(9):773-81.

11. Ripp JA, Bellini L, Fallar R, Bazari H, Katz JT, Korenstein D. The impact of duty hours restrictions on job burnout in internal medicine residents: a three-institution comparison study. Acad Med. 2015;90(4):494-9.

12. Shanafelt TD, Balch CM, Bechamps GJ, Russell T, Dyrbye L, Satele D, et al. Burnout and career satisfaction among American surgeons. Ann Surg. 2009;250(3):463-71.

13. Sloan S, Krishnamurthy M, Lyon DT, Mitri G, Chyshkevych I, Livert D. Work hour regulations: do we need further changes now? A survey of internal medicine faculty and residents. J Grad Med Educ. 2009;1(2):201-7.

14. Song MH, Tokuda Y, Nakayama T, Sato M, Hattori K. Intraoperative heart rate variability of a cardiac surgeon himself in coronary artery bypass grafting surgery. Interact Cardiovasc Thorac Surg. 2009;8(6):639-41.

15. Weight CJ, Sellon JL, Lessard-Anderson CR, Shanafelt TD, Olsen KD, Laskowski ER. Physical activity, quality of life, and burnout among physician trainees: the effect of a team-based, incentivized exercise program. Mayo Clin Proc. 2013;88(12):1435-42.

16. Zahrai A, Chahal J, Stojimirovic D, Schemitsch EH, Yee A, Kraemer W. Quality of life and educational benefit among orthopedic surgery residents: a prospective, multicentre comparison of the night float and the standard call systems. Can J Surg. 2011;54(1):25-32.

Appendices

Appendix A - REB approval letter

Western Research

Research Ethics

Western University Health Science Research Ethics Board
HSREB Amendment Approval Notice

Principal Investigator: Dr. Brent Lanting
Department & Institution: Schulich School of Medicine and Dentistry\Orthopaedic Surgery,London Health Sciences Centre

Review Type: Expedited
HSREB File Number: 104282
Study Title: Surgeon and Resident Stress Level: The Impact of Case Type and Surgeon Experience

HSREB Amendment Approval Date: September 22, 2015
HSREB Expiry Date: October 02, 2016

Documents Approved and/or Received for Information:

Document Name	Comments	Version Date
Other	270715 - The Physical Activity Readiness Questionnaire for Everyone - Version Sept 12 2011	2011/09/12
Other	270715 - Petrella Lab Exercise Stress Test Protocol	2015/07/27
Revised Western University Protocol	Received 17Sep15	
Revised Letter of Information & Consent		2015/09/17

The Western University Health Science Research Ethics Board (HSREB) has reviewed and approved the amendment to the above named study, as of the HSREB Initial Approval Date noted above.

HSREB approval for this study remains valid until the HSREB Expiry Date noted above, conditional to timely submission and acceptance of HSREB Continuing Ethics Review.

The Western University HSREB operates in compliance with the Tri-Council Policy Statement Ethical Conduct for Research Involving Humans (TCPS2), the International Conference on Harmonization of Technical Requirements for Registration of Pharmaceuticals for Human Use Guideline for Good Clinical Practice Practices (ICH E6 R1), the Ontario Personal Health Information Protection Act (PHIPA, 2004), Part 4 of the Natural Health Product Regulations, Health Canada Medical Device Regulations and Part C, Division 5, of the Food and Drug Regulations of Health Canada.

Members of the HSREB who are named as Investigators in research studies do not participate in discussions related to, nor vote on such studies when they are presented to the REB.

The HSREB is registered with the U.S. Department of Health & Human Services under the IRB registration number IRB 00000940.

This is an official document. Please retain the original in your files.

Western University, Research, Support Services Bldg., Rm. 5150
London, ON, Canada N6G 1G9 t. 519.661.3036 f. 519.850.2466 www.uwo.ca/research/ethics

Appendix B - STAI questionnaire

SELF-EVALUATION QUESTIONNAIRE STAI Form Y-1

Please provide the following information:

Name______________________________ Date____________ S____

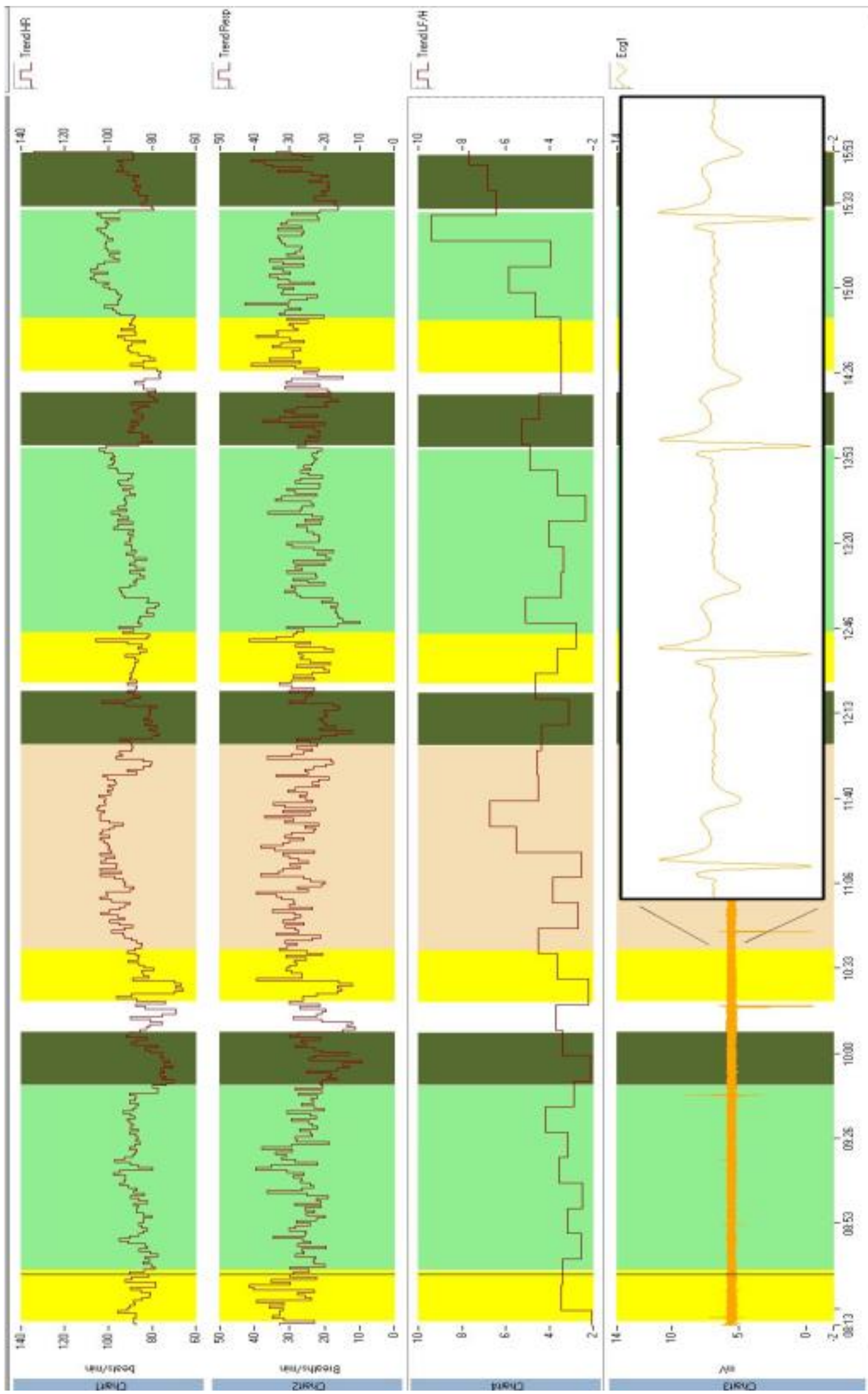
Age____________ Gender (*Circle*) M F T____

DIRECTIONS:

A number of statements which people have used to describe themselves are given below. Read each statement and then circle the appropriate number to the right of the statement to indicate how you feel *right* now, that is, *at this moment*. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer which seems to describe your present feelings best.

	NOT AT ALL	SOMEWHAT	MODERATELY SO	VERY MUCH SO
1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I am tense	1	2	3	4
4. I feel strained	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel satisfied	1	2	3	4
9. I feel frightened	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self-confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I am jittery	1	2	3	4
14. I feel indecisive	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4
18. I feel confused	1	2	3	4
19. I feel steady	1	2	3	4
20. I feel pleasant	1	2	3	4

Appendix C - Sample tracing of a surgery day



Appendix D - Standard Bruce protocol

Stage	Speed (km/h)	Speed (mph)	Gradient
1	2.74	1.7	10
2	4.02	2.5	12
3	5.47	3.4	14
4	6.76	4.2	16
5	8.05	5.0	18
6	8.85	5.5	20
7	9.65	6.0	22
8	10.46	6.5	24
9	11.26	7.0	26
10	12.07	7.5	28

Bruce RA, Kusumi F, Hosmer D (1973). Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. Am Heart J 85:546-582

Appendix E - Borg scale

Score	Exercise intensity	Intensity perception
0	None	
0.5	Very, very weak	(Just noticeable)
1	Very weak	
2	Weak	(Light)
3	Moderate	
4	Somewhat strong	
5	Strong	(Heavy)
6		
7	Very Strong	
8		
9	Very, very strong	(Almost maximal)
10	Maximal	

Borg G.A. Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise. 1982; 14:377-381.

Appendix F - Baseline stress test consent form

ST JOSEPH'S HEALTH CARE

LAWSON HEALTH RESEARCH INSTITUTE

THE CANADIAN CENTRE FOR ACTIVITY AND AGING

Informed Consent for a Health-Related Exercise Test

Explanation

You will perform an exercise test on a motor driven treadmill. The exercise intensity will begin at a level you can easily accomplish and will be advanced in stages depending on your fitness level. We may stop the test at any time because of signs of fatigue or you may stop when you wish because of personal feelings of fatigue or discomfort.

Risks and Discomforts

There exists the possibility of certain changes occurring. They include abnormal blood pressure, disorder of the heartbeat, and in rare instances a heart attack, stroke, or death. Every effort will be made to minimize these risks by evaluation of preliminary information relating to your health and fitness and by observations during the testing. Emergency equipment and trained personnel are available to deal with unusual situations that may arise.

Responsibilities of the Participant

Information you possess about your health status or previous experiences of unusual feelings with physical effort may affect the safety and value of your exercise test. Your prompt reporting of feelings with physical effort during the exercise test itself is of great importance. You are responsible to fully disclose such information when requested by testing staff.

Benefits

The results obtained from the exercise test may assist in the diagnosis of your health or in evaluating what type of physical activities you might do with low risk of harm.

Inquiries

Any questions about the procedures used in the exercise test or in the estimation of the functional capacity are encouraged. If you have any questions or concerns, please ask for further explanation.

Freedom of Consent

Your permission to perform this test is voluntary. You are free to deny consent or stop the test at any point if you so desire.

I HAVE READ THIS FORM AND I UNDERSTAND THE TEST PROCEUDRES THAT I WILL PERFORM. I CONSENT TO PARTICIPATE IN THIS TEST.

Date ____________________________ Physician ________________________

Patient Name ______________________ Witness _________________________

Patient Signature ____________________________________

2011

Curriculum vitae

Name:	Sarantis Abatzoglou, MDCM, FRCS(C)
Post-secondary Education and Degrees:	McGill University Montreal, Quebec, Canada 2005-2010 M.D.C.M.
	McGill University Montreal, Quebec, Canada 2010-2015 FRCS(C), Orthopaedic Surgery
	The University of Western Ontario London, Ontario, Canada 2015-2016 Clinical fellowship, Adult Hip and Knee Reconstructive Surgery
Honours and Awards:	American Association of Hip and Knee Surgery Resident course Grant 2013
	Resident Research day 3rd place prize, Orthopaedic Research Competition, Division of Orthopaedic Surgery, McGill University 2012
	Mach-Gaensslen Foundation of Canada Research Grant 2008
	Excellence study scholarship, Hellenic Scholarships Foundation 2007
	Dean's Honors list, Faculty of Medicine, McGill University 2007
Related Work Experience	Instructor Montreal Education Program on Health Prevention in high school students Montreal, Quebec 2007-2009
	Instructor McGill University Orthopaedics Interest Group Montreal, Quebec 2010-2015
	Instructor McGill University Medical Student MSK Physical examination teaching session

Montreal, Quebec
2012-2015

Organizer and Instructor
McGill University Orthopaedic Surgery Summer Anatomy Curriculum
Montreal, Quebec
2014-2015

Organizer and Instructor
McGill University Orthopaedic Surgery Bootcamp Curriculum
Montreal, Quebec
2014-2015

Resident Physician (Under the supervision of Dr Marc Burman)
Montreal Impact Soccer Club, Major Soccer League
Montreal, Quebec
2013-2014

Resident Physician (Under the supervision of Dr Paul Martineau)
Montreal Alouettes Football Club, Canadian Football League
Montreal, Quebec
2013

Orthopaedic surgeon
Lakeshore General Hospital
Montreal, Quebec
2016-

Peer-reviewed publications

1. **Abatzoglou S**, Turcotte RE, Adoubali A, Isler MH, Roberge D. Local Recurrence After Initial Multidisciplinary Management of Soft Tissue Sarcoma: Is There a Way Out? Clin Orthop Relat Res. 2010 Nov;468(11):3012-8.
2. **S Abatzoglou**, A Adoubali, C Wong, M Isler, RE Turcotte. Local Recurrence of Soft Tissue Sarcoma Following Primary Tumour Management by Musculoskeletal Oncology Teams. J Bone Joint Surg Br 2011 vol. 93-Bno. SUPP III 266
3. Marwan YA, **Abatzoglou S**, Esmaeel AA, AlQahtani SM, AlSulaimani SA, Tanzer M, Turcotte RE. Hip arthroscopy for the management of osteoid osteoma of the acetabulum: a systematic review of the literature and a case report. BMC Musculoskeletal Disorders. 2015; 16:318

Presentations at Regional, National & International Conferences

June 2016 — **S Abatzoglou**, B Lanting, J Thoren, X Yuan, J Howard, D Naudie, M Teeter. Femoral and tibial alignment affect baseplate fixation at 10-year follow-up measure using radiosterometric analysis. Annual Meeting of the Canadian Orthopaedic Association. Quebec City, QC. June 16-19, 2016 (Podium)

June 2013 — **S Abatzoglou**, GN Manoudis, LM Epure, DJ Zukor, OL Huk, J Antoniou. Two to eight year follow-up of a recalled hip resurfacing implant. 47th Annual Meeting of the Canadian Orthopaedic Research Society. Winnipeg, MB. June 20-22, 2013. (Podium)

June 2013	**S Abatzoglou**, N Papadopoulos, GN Manoudis, LM Epure, DJ Zukor, OL Huk, J Antoniou. Clinical, metal ion and oxidative stress markers comparison of 36mm, 40mm and 44mm MM total hip arthroplasty. 4 year follow-up. 47th Annual Meeting of the Canadian Orthopaedic Research Society. Winnipeg, MB. June 20-22, 2013. (Podium)
Feb 2012	N Papadopoulos, **S Abatzoglou**, GN Manoudis, LM Epure, DJ Zukor, OL Huk , J Antoniou Clinical outcome, metal ions and oxidative stress markers comparison of 36mm, 40mm and 44mm metal-on-metal total hip arthroplasty. Annual Meeting of the American Academy of Orthopedic Surgeons and 58th Annual Meeting of the Orthopaedic Research Society. San Francisco, CA. February 4-11, 2012. (Poster)
July 2009	**S Abatzoglou**, A Adoubali, C Wong, M Isler, RE Turcotte. Local Recurrence of Soft Tissue Sarcoma Following Primary Tumour Management by Musculoskeletal Oncology Teams, 64th annual meeting of the Canadian Orthopaedic Association, Whistler, BC, July 4-5, 2009 (Podium)