BIOMECHANICAL OPTIMIZATION OF SURGICAL SKILLS : INFLUENCE OF HEIGHT ADJUSTMENT OF SURGICAL TABLE ON MOVEMENTS ACCURACY AND MUSCULAR FATIGUE

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The purpose of this study was to investigate the influence of the height of the surgical table on movements accuracy and muscular fatigue, as well as on alignment of mechanical axes at the wrist and at the shoulder level. A "standard" table height was compared with an "ergonomic" height which was set 10% lower. Nine (9) first year residents in surgery performed a surgical procedure and were evaluated on movements accuracy and shoulder muscular fatigue. Results obtained with the table set at "ergonomic" height demonstrated higher accuracy ($p \leq 0.01$) and less shoulder fatigue ($p \leq 0.01$), as well as smaller deviations from neutral position both at the shoulder level ($p \leq 0.01$) and at the wrist level ($p \leq 0.03$).

KEY WORDS: occupational biomechanics, surgical skills, movement efficiency, ergonomics, surgical table.

INTRODUCTION: A competency-based surgery residents training program with a biomechanical-kinesiological approach has been experimented at the University of Sherbrooke in order to improve procedural learning and mastery of invasive skills (Wanzel et al., 2002; Anastakis et al., 2000; Cauraugh et al., 1999; Martin et al., 1998). Principles of biomechanics and kinesiology have been taught and applied to many aspects of surgical tasks, including segments alignment, body positioning and posture (Therrien et al., 2001). However, improper height adjustment of the surgical table has often been identified as a limiting factor preventing residents from attaining maximal precision and efficiency (Emam et al., 2001; Chaffin et al., 1999; Szabo et al., 1994) in the performance of surgical procedures. The purpose of the present study was to investigate the influence of the height of the surgical table, in relationship with individual morphology, on movement accuracy and muscular fatigue at the shoulder joint, as well as on changes in the alignment of mechanical axes at the wrist and at the shoulder level. Table height, hand deviations from neutral position about the wrist joint and arm abduction about the shoulder joint have of ten been identified in the ergonomic literature as factors limiting the precision of movements and inducing fatigue in muscles responsible of upper limb movements (Chaffin et al., 1999; Chaffin, 1992; Wiker et al., 1989).

METHODS : Subjects were nine (9) first year residents in surgery selected at random among all those who were volunteers for the study and had not been previously exposed to ergonomic principles on table height adjustment. A pilot study conducted in actual operating room setting had previously disclosed information on adjustment height preferred by surgeons while performing an hemicolectomy procedure. Two table heights were selected for the main study : 1) the table height adjusted in such a way that the forearms of the operating surgeon were parallel to the top of the operating site when standing with elbows flexed 90°; 2) an ergonomically optimal height, in which the table was set 10% lower. Each subject had to perform an hemicolectomy procedure for one (1) hour on a fresh cadaver at each table height, under the supervision of an expert surgeon. The order was selected at random and subjects were not informed of the table setting. A star-shaped tracing test ($r = 0.995$), with an instrumented Metz scissor, was used to measure movements accuracy, while muscular fatigue was evaluated with a static shoulder endurance test (Chaffin, 1973); these tests were administered both at rest and after each surgical procedure. Performance of subjects was also recorded with three (3) videocameras (2 above, 1 sideways) in order to allow fine biomechanical and kinesiological analyses of body positions and segmental movements.

RESULTS : Analysis of results (non-parametric, Wilcoxon) disclosed that the number of errors, while performing the accuracy test, was significantly lower ($\bar{X} = 4.81 \pm 3.22$ vs $\bar{X} =$

5.74 ± 3.21), ($p < 0.01$), while execution time stayed the same, following surgical procedures with the table set at optimal ergonomic height. (Figure 1)

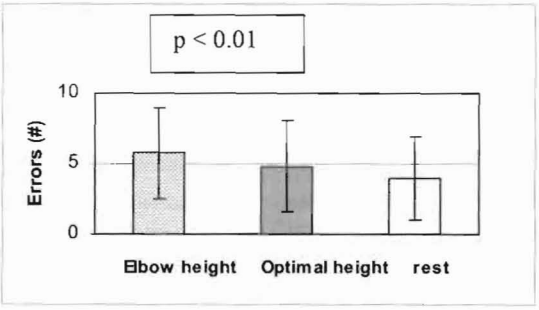

Figure 1. Accuracy test results.

Results also demonstrated that static endurance of shoulder muscles was significantly higher ($\bar{X}$ = 129.88 sec., ± 31.50 sec vs $\bar{X}$ = 124.95 sec., ± 33,18 sec), ($p < 0.01$), after performing at the same optimal height condition. (Figure 2)

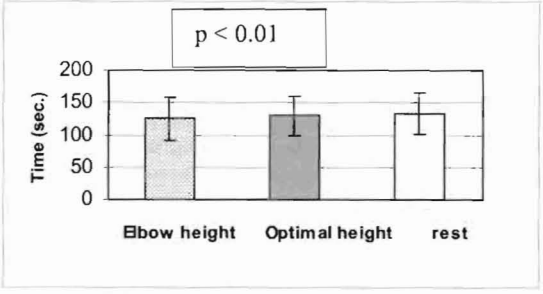

Figure 2. Resistance to shoulder muscular fatigue.

Moreover, results from video analysis disclosed that the subjects spent significantly ($p < .01$) less time with the upper arm deviated from the neutral position ($\bar{X}$ = 74.11 sec., ± 28.89 sec vs $\bar{X}$ = 142.78 sec., ± 51.87 sec), (Figure 3), as well as significantly ($p < .03$) less time with the wrist deviated from the neutral position ($\bar{X}$ = 82.44 sec., ± 50.36 sec vs $\bar{X}$ = 109.67, ± 55.08), (Figure 4), when the height of the operating table was optimally adjusted according to ergonomic principles.

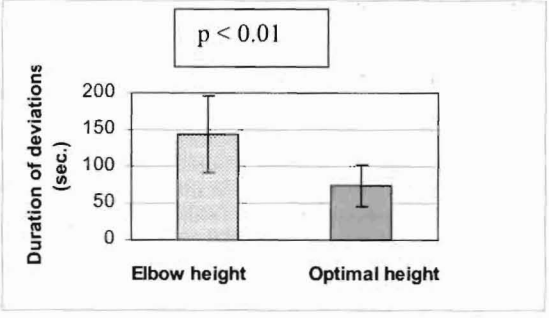

Figure 3. Shoulder deviations from neutral position.

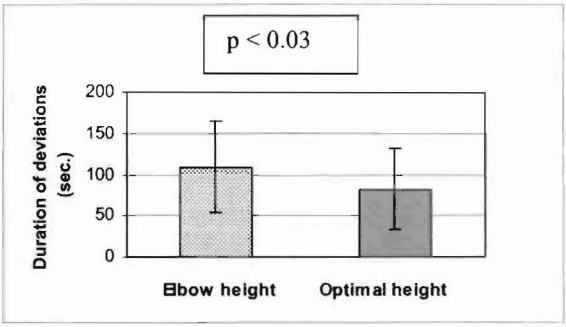

Figure 4. Wrist deviations from neutral position.

DISCUSSION AND CONCLUSION: These results are interpreted as an indication that movement accuracy can be improved and muscular fatigue can be decreased when setting the surgical table at an optimal ergonomic height to perform surgical procedures similar to the one used in this study. The results obtained from the video data also indicate that setting the surgical table at an ergonomically optimal height favors better alignment of mechanical axes at both the hand and the upper arm level, which, in turn, could be considered a biomechanically logical explanation for the improved performance observed in such a condition. Moreover, the results of this study shed more light on the pertinence of integrating selected knowledge from biomechanics and ergonomics into a kinesiological approach to complement the learning and training programs of surgery residents, in order to favor an optimization of their procedural skills. The outcome of the present research clearly indicates that medical education, surgical training in particular, can benefit from biomechanics knowledge, evaluation techniques and tools. This is a promising new area of application for biomechanics and biomechanicians.

REFERENCES :

Anastakis, D. J., Hamstra, S. J. & Matsumoto, E. D. (2000). Visual-spatial abilities in surgical training. *American Journal of Surgery*, **179** (6), 469-471.

Cauraugh, J. H., Martin, M. & Komer-Martin, K. (1999). Modeling surgical expertise for motor skill acquisition. *American Journal of Surgery,* **177**, 331-336.

Chaffin, D.B. (1973). Localized muscle fatigue: Definition and measurement. *Journal of Occupational Medicine,* **15** (4), 346-354.

Chaffin, D.B., Andersson, G.B.J. & Martin, B.J. (1999). *Occupational Biomechanics* (3rd ed.), New York: Wiley-Interscience.

Emam, T.A., Frank, T.G. Hanna, T.G. & Cuschieri, A. (2001). Influence of handle design on the surgeon's upper limb movements, muscle recruitment, and fatigue during endoscopic suturing. *Surgical Endoscopy*, **15** (7), 667-672.

Martin, M., Vashisht, B., Frezza, E., Ferone, T., Lopez, B., Pahuja, M. & Spence, R.K. (1998). Competency-based instruction in critical invasive skills improves both resident performance and patient safety. *Surgery*, **124** (2), 313-317.

Szabo, Z., Hunter, J., Berci, G. Sackier, J. & Cuschieri, A. (1994). Analysis of surgical movements during suturing in laparoscopy. *Endoscopic Surgery Allied Technology*, **2** (1), 55-61.

Therrien, R., Martin, M. & Prince, F. (2001). A biomechanical and kinesiological approach in the teaching of efficient surgical skills to medical students. In *Proceedings of XIX International Symposium on Biomechanics in Sports* (pp. 202-206), John R, Blackwell, (Ed.). San Francisco, CA: International Society of Biomechanics in Sports.

Wanzel, K.R., Hamstra, S.J., Anastakis, D.J., Matsumoto, E.D. & Cusimano, M.D. (2002). Effect of visual-spatial ability on learning of spatiallly-complex surgical skills. *Lancet*, **359** (9302), 230-231.

Wiker, S.F., Langolf, G.D. & Chaffin, D.B. (1989). Arm posture and human movement capability. *Human Factors*, **31** (4), 421-441.