Ovidius University Annals, Series Physical Education and Sport / SCIENCE, MOVEMENT AND HEALTH
29 code CNCSIS category B+, Vol. 11, ISSUE 1, 2011, Romania
The journal is indexed in: 1. SPORTDiscus, Ebsco, INDEX COPERNICUS JOURNAL MASTER LIST. 2. DOAJ DIRECTORY OF OPEN ACCES JOURNALS

STRENGTH AND MYOELECTRIC ACTIVITY OF VARIOUS MUSCLES IN RELATION TO THE VARIOUS MOVEMENTS PERFORMED AT THE LEVEL OF THE SPINE – A LITERATURE REVIEW

STRATON ALEXANDRU, PhD [1], GIDU DIANA, PhD [1]
[1] Ovidius University of Constanta, Faculty of Physical Education and Sport, ROMANIA
axelcorro@yahoo.com

Abstract
Background: Knowing the value of maximum isometric strength and myoelectrical activity in every movement for the spine muscles for sedentary subjects and athletes, may be important in designing rehabilitation programs and training programs, especially in designing the optimal volume of training.
Aim: The setting of maximal isometric strength generation and myoelectrical activity of antagonist muscle that support the spine, realised in various movements at the level of the spine and the implications of the data found.
Key words: spine, muscle, maximal isometric strength.

Introduction

Instability of the trunk muscles can lead to biomechanical overload of the spine, which is due to control movement and suboptimal muscle recruitment (D.C. Guzik, T.S. Keller, M. Szpalski, J.H. Park, D.M. Spengler, 1996).Therefore, a closer analysis of strength generation and myoelectrical activity of antagonist muscle that support the spine can lead to a correct and efficient implementation of training and rehabilitation programs at the level of the trunk.

Strength and myoelectric activity of various muscles in relation to the various movements performed at the level of the spine.

Maximum voluntary muscle contraction of the cervical spine generates high electromyographic signal intensity for most muscles which participate in lateral rotation movements. The highest level of electromyographic signal was recorded for trapezius muscle in lateral rotation movement in all subjects tested. Also, isometric peaks force for the movement of extension was 28,3 ± 3,3Nm (Newton*meters), for the movement of flexion was 17,7 ± 3,1Nm, for right lateral flexion movement was 17 ± 2.9Nm, and for left lateral flexion movement was 16,9 ± 2,9Nm (H. Choi, R.Jr. Vanderby, 2000). A.N. Vasavada, S. Li, S.L. Delpi, (2001), showed that the cervical extensor muscles exert a force of 52 ± 11Nm for male subjects and 21 ± 12Nm for female subjects, the cervical musculature required making the movement of flexion exert a force of 30 ± 5Nm for male subjects and 15 ± 4Nm for female subjects, the muscles necessary to carry out cervical lateral flexion movement exert a force of 36 ± 8Nm for male subjects and 16 ± 8Nm for female subjects and cervical muscles necessary to carry out lateral rotational movement exert a force of 15 ± 4Nm for male subjects and 6 ± 3Nm for female subjects.Romanian female subjects, with an average age of $34^{6} \pm 8^{4}$ ($\text{years}^{\text{months}}$), presents a balanced cervical girdle muscle strength for performing movements in sagittal plane and frontal plane, which recorded a maximal isometric strength of 13,6 ± 11Nm for the movement of flexion, 27,53 ± 14,37Nm for the movement of extension, 19,4 ± 9,16Nm for the movement of right lateral flexion and 20,26 ± 11,42Nm for the movement of left lateral flexion. Romanian male subjects, with an average age of $35^{5} \pm 13^{10}$ ($\text{years}^{\text{months}}$), develops a maximum isometric strength significantly higher compared to female subjects, for the movements of flexion, extension, right lateral flexion and left lateral flexion at the level of the cervical spine (A. Straton, 2007a).

Much of the literature showed that the maximal isometric strength necessary to carry out the movement of extension is significantly higher than the maximal isometric strength necessary to carry out the movements of flexion (S. Kumar, Y. Narayan, T. Amell, 2001; K.Y. Seng, V.S. Lee Peter, P.M. Lam, 2002; A. Straton, 2007a; L. Suryanarayana, S. Kumar, 2005) and anterior-lateral flexion, at the level of cervical spine. Also, male subjects develop a maximal isometric strength significantly higher at the level of the cervical spine than female subjects (S. Kumar, Y. Narayan, T. Amell, 2001), with a magnitude of 1,2-1,7 times higher (T.T. Chiu, T.H. Lam, A.J. Hedley, 2002).

S. Kumar, Y. Narayan, T. Amell, R. Ferrari, (2002), showed that the results estimation of maximal isometric strength at the level of cervical spine, performed in a neutral position, were the largest in extension and the lowest in flexion, showing a gradual decrease in maximum isometric strength results from the movement of extension, continued with the results obtained in posterior-lateral movement, lateral flexion movement, anterior-lateral flexion movement and ending with results from the movement of flexion. Also, electromyographic intensity was approximately 66% higher for muscles necessary to carry out the movement of flexion then the muscles necessary to carry out the extension movement (even if the maximal isometric strength was higher by about 30% for muscle which carried out extension movement, then the muscles which carried out movement of flexion), suggesting a higher relative myoelectical activity of muscles performing the movement of flexion then muscles performing the movement of extension, towards the generation of certain forces.T.T. Chiu, T.H. Lam, A.J. Hedley, (2002), showed that male subjects develop a maximal isometric strength at the level of the cervical spine, significantly higher for muscles required for right lateral flexion movement then muscles needed to realise left lateral flexion movement. Also, female subjects do not have disbalances of isometric muscles strength peaks between right lateral flexion movement and left lateral flexion movement.

Female subjects trend to present similar levels of maximal isometric strength, reported to age groups between 20 and 59 years old, for muscles of the cervical spine, for movements of flexion (73,8 ± 20N), extension (190,8 ± 31,3 N), right lateral rotation (8,1 ± 2,3 Nm) and left lateral rotation (7,9 ± 2,3 Nm) (P.K. Salo, J.J. Ylinen, E.A. Mälkiä, H. Kautiainen, A.H. Häkkinen, 2006).A gradual increase of muscle contraction in lateral rotation movement at the level of thoraco-lumbar spine, is performed concomitantly with significantly increasing the force developed by the great dorsal muscle and external oblique abdominal muscle and decreasing the force developed by extensor muscles of the spine, suggesting the role of extensor muscles of the spine as stabilizer and not as rotator (S. Kumar, Y. Narayan, D. Garand, 2002).Muscles that contribute to the lateral rotation movement, is participating with a contribution of about 65% of the total myoelectric activity and the return to neutral position can be attributed to elastic controlled rebound of the same muscles. Abdominal oblique muscles, latissimus dorsi muscles and spine extensors, were the first muscles which presented myoelectric activity in lateral rotation movement. In an amplitude of lateral rotation movement in both directions for about 10º-15º, muscle contraction for executing those movements is reduced; over this amplitude osteo-ligament structures become rigid, and muscle contraction increases for the execution of rotational movements (S. Kumar, Y. Narayan, M. Zedka, 1996).W.S. Marras, K.G. Davis, K.P. Granata, (1998), showed that lateral rotation movement executed in standing position is generated by contraction of internal and external oblique abdominal muscles and of the latissimus dorsi muscles contraction. Also, lateral rotation movement, with trunk flexed, produce an increase in myoelectric activity of spine extensors by 10-15% and a decrease in myoelectric activity of the external oblique abdominal muscles with approximately 3-5%. A. Toren, (2001) showed that the external oblique abdominal muscles and spine extensor muscles presents a pattern of myoelectric activation significantly different in relation to the direction of rotation. These results suggest a careful choice of methods to assess muscle activity, reported to occupational (W.S. Marras, K.G. Davis, K.P. Granata, 1998) and sporting activities.Production capacity of trunk muscles strength is dependent on posture and decreases with increasing lateral rotation angle. Increasing the angle of lateral rotation and lateral flexion is reflected by the increase of electromyographic signal. This shows that asymmetrical movement requires more muscular effort to generate a lower force. Asymmetrical movement tends to destabilize the osteo-ligament and muscles system from the level of spine, increasing, in this way, the chances of injury (S. Kumar, Y. Narayan, 2006). The results obtained by W.S. Marras and K.P. Granata, (1995), for different dynamic movements performed in the spine may help explain, from biomechanics perspectives, why the vast majority of epidemiological studies have identified rotation movement as a risk factor for problems at the lumbar spine. Anyway, these disbalances can be corrected by applying a corrective exercise program in the lumbar muscles (T. Renkawitz, D. Boluki, O. Linhardt, J. Grifka, 2007).

Simultaneous activation of antagonistic muscles required for flexion and extension movements is present in maintaining neutral spine posture. Simultaneous activation of antagonistic muscles required for flexion and extension movements increases by applying the torso an additional weight. This simultaneous activation of antagonistic muscles required for flexion and extension movements, can be explained entirely by the need of neuromuscular system to provide mechanical stability to the spine (J. Cholewicki, M.M. Panjabi, A. Khachatryan, 1997). Also, spine posture is affected by the force developed by toraco-lumbar extensor muscles, which, mainly, decreases with age (M.S. Eagan, D.A. Sedlock, 2001; P.J. Limburg, M. Sinaki, J.W. Rogers, P.E. Caskey, B.K. Pierskalla, 1991; M. Sinaki, S. Khosla, P.J. Limburg, J.W. Rogers, P.A. Murtaugh, 1993). Spine extensor muscles weakness can be the result, in respect with age, by motor units number decline, by progressive habitual inactivity, by reduced recruitment of motor units (R.G. Miller, 1995) or by the inhibition caused by pain.In addition to the role of muscle activity, to maintain the correct posture of the spine, should be taken into account the control of muscle activity. Muscles that support the spine, should provide stability and controlled movement of the structure. To provide stability and optimal control of movements, the muscles of the spine must have sufficient strength and resistance, and correct and adequate model of muscle recruitment (M.M. Panjabi, 1992). Neuromuscular control is associated directly with the central nervous system to ensure optimal muscle performance.Generation of force at the level of antagonistic muscles which support the spine, in athletes, depends primarily on the specific movements, corresponding to the sport practiced, realised at the level of the trunk. K. Iwai, T. Okada, K. Nakazato et al., (2008), showed that the maximum force produced by extensor and flexor muscles of the trunk is stronger in wrestlers than judokas. Also, the cross sectional area of abdominal muscle is significantly greater in wrestlers than judokas, and the cross sectional area of oblique abdominal muscles and quadratus lomborum is significantly higher in judokas than wrestlers. Therefore, the development of muscle strength in athletes is appropriate to the sport specific movements practiced.In most cases, maximal isometric strength recorded at the level of the trunk muscles in sedentary subjects is significantly lower compared with performance athletes. In the study of M. Hasue, M. Fujiwara, S. Kikuchi, (1980), is showing that female subjects, aged between 30 and 39 years, develops a maximal isometric strength of trunk extensors of 137,3 ± 21,4Nm and a maximal isometric strength of flexor muscles of the trunk of 90 ± 18,3Nm; in addition male subjects, aged between 30 and 39 years, develops a maximal isometric strength of trunk extensors of 209,5 ± 25,5Nm and a maximal isometric strength of flexor muscles of the trunk of 168,9 ± 34,4Nm.T. McNeill, D. Warwick, G. Andersson, A. Schultz, (1980), showed, after the test of maximal isometric strength in standing position, that the female subjects generates in extension movement of 117Nm, and a maximal isometric strength for flexion movement of 87Nm; also, male subjects generates a maximal isometric strength in extension movement of 210Nm and a maximal isometric strength in flexion movement of 149Nm.

A. Straton, (2007b) showed that extensor muscles from the toraco-lumbar spine developed a maximal isometric strength of 266,041 ± 82,744Nm for male subjects and 141,333 ± 84,886Nm for female subjects, at the angle of 30°, and flexor muscles at the level of thoraco-lumbar spine developed a maximal isometric strength of 184,291 ± 47,760Nm for male subjects and 98,133 ± 52,787Nm for female subjects, at the angle of 0 º. In female subjects, maximal isometric strength exerted by the muscles necessary to carry out the movement of left lateral flexion (115,266 ± 44,117Nm) was significantly higher than the maximum isometric strength exerted by the muscles necessary to carry out right lateral flexion movement (103,600 ± 54,517Nm), at the angle of -30 º. In male subjects, no significant differences were found between maximal isometric strength exerted by the muscles necessary to carry out right lateral flexion movement (189,291 ± 63.358 Nm) and left lateral flexion (194.291 ± 61.940 Nm) at the same angle. However, in a study realised on 16 male subjects, significant differences were found between maximal isometric strength developed by muscles necessary to carry out right lateral flexion movement and muscles necessary to carry out the left lateral flexion movement (D.C. Guzik, T.S. Keller, M. Szpalski, J.H. Park, D.M. Spengler, 1996). In both sexes, maximal isometric strength exerted by the muscles responsible for of right lateral rotation movement (131,666 ± 62,741Nm for male subjects and 62,466 ± 24,189Nm for female subjects) was not significantly different from maximal isometric strength exerted by muscles responsible for left lateral rotation movement (134,625 ± 58,560Nm for male subjects and 63,866 ± 30,123Nm for female subjects) (A. Straton, 2007b).Also, the female subjects aged between 30 and 40 years, exerted a maximal isometric strength by the muscles necessary to carry out the left side flexion movement at all angles tested (82,286 ± 24,688Nm at -30° angle, 101,333 ± 25,784Nm at 0º angle, and 73,095 ± 21,624Nm at 30° angle) significantly higher than the maximal isometric strength exerted by the muscles necessary to carry out right lateral flexion movement (73,524 ± 23,183Nm at -30° angle, 87,714 ± 24,956Nm at 0° angle, and 65,905 ± 21,84Nm at 30° angle). Maximal isometric strength exerted by the muscles necessary to carry out the right rotational movement at all angles tested (59,571 ± 17,509Nm at -30° angle, 49,143 ± 15,841Nm at 0° angle, and 35,905 ± 12,124Nm at 30° angle) is not significant different than maximal isometric strength exerted by the muscles necessary to carry out the left rotational movement (54,333 ± 18,386Nm at -30° angle, 44,238 ± 16,655Nm at 0° angle, and 32,238 ± 13,206Nm at 30° angle). In the same study, the toraco-lumbar spine extensor muscles has developed a maximal isometric strength of 99,857 ± 29,294Nm at 0° angle and 123,571 ± 34,661Nm at 30° angle and flexor muscles has developed a maximal isometric strength of 80,381 ± 18,829Nm at 0° angle and 86,667 ± 19,51Nm at 30° angle (A. Straton, G. Cismaş, 2009).

Conclusions

Data presented in this paperwork review establish some directions in implementing programs for training and rehabilitation programs at the level of the spine. However, this paperwork review requires a closer analysis of maximal isometric strength generation and myoelectric activity of antagonistic muscles that support the spine, for the setting of optimal training or rehabilitation programs.

Bibliography

CHIU, T. T., LAM, T. H., HEDLEY, A. J., 2002, *Maximal isometric muscle strength of the cervical spine in healthy volunteers.* Clinical rehabilitation, 16 (7): 772-779.

CHOI, H., VANDERBY, R. Jr., 2000, *Muscle forces and spinal loads at C4/5 level during isometric voluntary efforts.* Medicine and science in sports and exercise, 32 (4): 830-838.

CHOLEWICKI, J., PANJABI, M. M., KHACHATRYAN, A., 1997, *Stabilizing function of trunk flexor-extensor muscles around a neutral spine posture.* Spine, 22 (19): 2207-2212.

EAGAN, M. S., SEDLOCK, D. A., 2001, *Kyphosis in active and sedentary postmenopausal women.* Medicine and science in sports and exercise, 33 (5): 688-695.

GUZIK D. C., KELLER, T. S., SZPALSKI, M., PARK, J. H., SPENGLER, D. M., 1996, *A biomechanical model of the lumbar spine during upright isometric flexion, extension and lateral bending.* Spine, 21 (4): 427-433.

HASUE, M., FUJIWARA, M., KIKUCHI, S., 1980, *A new method of quantitative measurement of abdominal and back muscle strength.* Spine, 5 (2): 143-148.

IWAI, K., OKADA, T., NAKAZATO K., FUJIMOTO, H., YAMAMOTO,, Y., NAKAJIMA, H., 2008, *Sport-specific characteristics of trunk muscles in collegiate wrestlers and judokas.* Journal of strength and conditioning research/National Strength & Conditioning Association, 22 (2): 350-358.

KUMAR, S., NARAYAN, Y., 2006, *Torque and EMG in rotation extension of the torso from pre-rotated and flexed postures.* Clinical biomechanics (Bristol, Avon), 21 (9): 920-931.

KUMAR, S., NARAYAN Y., AMELL, T., 2001, *Cervical strength of young adults in sagittal, coronal, and intermediate planes.* Clinical biomechanics (Bristol, Avon), 16 (5): 380-388.

KUMAR, S., NARAYAN, Y., AMELL, T., FERRARI, R., 2002, *Electromyography of superficial cervical muscles with exertion in the sagittal, coronal and oblique planes.* European spine journal: official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society, 11 (1): 27-37.

KUMAR, S., NARAYAN, Y., GARAND, D., 2002, *Electromyography of trunk muscles in isometric graded axial rotation.* Journal of electromyography and kinesiology: Official journal of the International Society of Electrophysiological Kinesiology, 12 (4): 317-328.

KUMAR, S., NARAYAN, Y., ZEDKA, M., 1996, *An electromyographic study of unresisted trunk rotation with normal velocity among healthy subjects.* Spine, 21 (13): 1500-1512.

LIMBURG, P. J., SINAKI, M., ROGERS, J. W., CASKEY P. E., PIERSKALLA B. K., 1991, *A useful technique for measurement of back strength in osteoporotic and elderly patients.* Mayo Clinic Proceedings, 66: 39-44.

MARRAS W. S., DAVIS K. G., GRANATA K. P., 1998, *Trunk muscle activities during asymmetric twisting motions.* Journal of electromyography and kinesiology: official journal of the International Society of Electrophysiological Kinesiology, 8 (4): 247-256.

MARRAS, W. S., GRANATA, K. P., 1995, *A biomechanical assessment and model of axial twisting in the thoracolumbar spine.* Spine, 20 (13): 1440-1451.

MCNEILL, T., WARWICK, D., ANDERSSON, G., SCHULTZ A., 1980, *Trunk strengths in attempted flexion, extension, and lateral bending in healthy subjects and patients with low-back disorders.* Spine, 5 (6): 529-538.

MILLER, R. G., 1995, *The effects of aging upon nerve and muscle function and their importance for neurorehabilitation.* Journal of Neurorehabilitation and Neural Repair, 9 (3): 175-181.

PANJABI, M. M., 1992, *The stabilizing system of the spine: Function, dysfunction, adaptation and enhancement.* Journal of Spinal Disorders, 5 (Part 1): 383-389.

RENKAWITZ, T., BOLUKI D., LINHARDT, O., GRIFKA, J., 2007, *Neuromuscular imbalances of the lower back in tennis players--the effects of a back exercise program.* Sportverletz Sportschaden, 21 (1): 23-28.

VASAVADA, A. N., LI S., DELP, S. L., 2001, *Three-dimensional isometric strength of neck muscles in humans.* Spine, 26 (17): 1904-1909.

SALO, P. K., YLINEN J. J., MÄLKIÄ, E. A., KAUTIAINEN, H., HÄKKINEN, A. H., 2006, *Isometric strength of the cervical flexor, extensor, and rotator muscles in 220 healthy females aged 20 to 59 years.* The journal of orthopeadic and sports physical therapy, 36 (7): 495-502.

SENG, K. Y., LEE, PETER V. S., LAM, P. M., 2002, *Neck muscle strength across the sagittal and coronal planes: an isometric study.* Clinical Biomechanics (Bristol, Avon), 17 (7): 545-547.

SINAKI, M., KHOSLA, S., LIMBURG, P. J., ROGERS J. W., MURTAUGH, P. A., 1993, *Muscle strength in osteoporotic versus normal women,* Osteoporosis international: A journal established as result of cooperation between the European Foundation for Osteoporosis and the National Osteoporosis Foundation of the USA, 3: 8-12.

STRATON, A., 2007a, *Diferenţe între sexe privind forţa izometrică maximă şi mobilitatea maximă la nivelul coloanei cervicale,* Sesiunea ştiinţifică internaţională "Competenţă şi Performanţă în Domeniul Culturii Fizice", ANEFS, Bucureşti, 16 iunie 2007: [articol în format electronic pe CD-ROM].

STRATON, A., 2007b, *Differences between genders regarding maximal isometric force at the level of lumbar-thoracic column.* Conferinţa Ştiinţifică Internaţională, „Educaţie fizică şi sport în viziune europeană", Analele Universităţii Ovidius Constanţa, Seria Educaţie Fizică şi Sport, Vol. 7, Seria 7, Ovidius University Press, 19 mai 2007, Constanţa: 559-569.

STRATON ,A., CISMAŞ G., 2009, *Diferenţe de forţă izometrică maximă între diferite unghiuri şi diferite tipuri de mişcări ale trunchiului la subiecţii de gen feminin.* Palestrica mileniului III, Civilizaţie şi Sport, vol. 10, 1 (35): 83-89.

SURYANARAYANA, L., KUMAR S., 2005, *Quantification of isometric cervical strength at different ranges of flexion and extension.* Clinical Biomechanics (Bristol, Avon), 20 (2): 138-144.

TORÉN, A., 2001, *Muscle activity and range of motion during active trunk rotation in a sitting posture.* Applied ergonomics, 32 (6): 583-591.