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Differences in back extensor muscles fatigability for smoking and non-smoking athletes

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Abstract. *Background and objective:* Empirical research on the influence of smoking on musculoskeletal health in athletes is sparse. The objective of this study was to compare back extensor muscles' strength (BEMS) before and after a fatigue induction protocol among smoking and non smoking male athletes. A pretest – posttest design was used to determine the difference in BEMS between smoking ($N = 52$) and non smoking ($N = 52$) athletes aged 18 and 30. A back and leg dynamometer was used to quantify BEMS while repetitive prone chest raise test was used to induce fatigue of the back extensor muscles. The smoking (23.1 ± 2.9 years) and non-smoking athletes (23.2 ± 2.37 years) were comparable in age ($p = 0.855$). Smoking athletes exhibited a significantly higher rating of perceived exertion ($p = 0.007$) and fatigue index (10.76% vs. 5.07%); and significant reduction in BEMS following fatigue induction ($p < 0.05$) compared with their non smoking counterparts. Smoking athletes have higher rates of muscular fatiguability and decreased back strength following back extensors tasks. Smoking is associated with increased muscle fatiguability and impairment of back strength in athletes.

Keywords: Back extensors, dynamometer, muscle strength, smoking, athletes

1. Introduction

The prevalence of cigarette smoking is reported to have increased especially in the developing countries [10,36,40,57]. Cigarette smoking is believed to constitute a significant and substantial problem affecting the general health status of the society. Smoking has been found to have a negative impact on musculoskeletal health [2,22,51]. Some studies reported a strong association between smoking and back pain [13, 18,19,27,52], others concluded that smoking is a weak risk factor for low back pain (LBP) [20,33], while others found no significant association [12,15]. The causal mechanism as well as the confounding factors on the relationship between smoking and back pain are still uncertain. Quite a few theories have been proposed for this association; some studies indicate that smoking leads to malnutrition of intervertebral disc by affecting blood flow, rendering the intervertebral disc susceptible to mechanical stress [11,14,16,35], other studies linked to back pain in smokers to tissue hypoxia and malnutrition [16,35], coughing [28], osteoporosis [41,53] and lifestyle [13]. Goldberg et al. [20] indicated that none of these proposed mechanisms has been clinically expounded.

Al-Obaidi et al. [1] submitted that the strength of the back extensor muscles in individuals with or without LBP has been extensively studied. However, most of the studies did not control or account for the influence of smoking on back extensors' strength. Karpovic and Creighton [26] suggested that there was no convincing proof of an immediate harmful effect of smoking

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upon athletic performance while Al-Obaidi et al. [1] submitted that cigarette smoking was associated with poor physical fitness and muscle strength among athletes. Smoking is believed to be detrimental to athletic performance because it leads to premature fatigue or muscular failure which may in turn affect athletic performance [49,50]. However, empirical research on the influence of cigarette smoking on musculoskeletal health in athletes is sparse. This study was designed to investigate the hypothesis that athletes who smoke would have greater back extensor muscle fatigue as well as decreased back extensors' strength compared to non-smoking athletes following a fatigue induction protocol.

2. Method

2.1. Participants

The study used a pretest – posttest design to determine the difference in BEMS between smoking and non smoking athletes. A total of 104 (52 smoking and 52 non smoking) male athletes aged 18 and 30 years of the Obafemi Awolowo University, Ile – Ife, Nigeria were recruited into the study. The athletes were in full and active training preparatory for the Nigeria University Games, a biennial sports fiesta showcasing athletes from Nigerian universities competing in 15 different sports including athletics (track and field events including running, throwing and jumping), badminton, basketball, chess, cricket, English football, Olympic style handball, hockey, judo, table tennis, tae-kwon-do, tennis, squash, swimming, and volleyball.

The participating athletes in this study were screened via interview to ensure that they satisfy the selection criteria for the study. Demographic data including smoking history were obtained from the participants. Exclusion criteria were a history of symptomatic low back pain within one year to the time of the study, any obvious spinal deformity or defect of the upper or lower limbs or other disability limiting the ability to exercise, being involved in any prior systematic exercise program of the lumbar extensor muscles as at the time of the study, or a history of cardiovascular diseases representing contraindications to exercise. Data were also obtained on height and weight following standardized procedures and body mass index (BMI) were also recorded.

The ethical approval for this study was obtained from the ethics and research committee of the Obafemi Awolowo University Teaching Hospitals Complex Ile – Ife, Nigeria. The athletes were fully informed about the purpose of the study and their consents were obtained before measurements were taken.

2.2. Study procedure

The study procedure involved five stages. 1) Warm-up – the athlete was involved in a 5-minute exercise including head rotation, shoulder-level arm swing, alternate leg bends, side bends, alternate leg stretch and waist circles. 2) Assessment of BEMS before the fatigue induction protocol. 3) Fatigue induction protocol using repetitive prone chest raise – a series of repeated extension motions. The test was standardized by motion velocity performed at 30°/s. 5–10-s rest period was allowed to enable preparation for testing after fatigue induction protocol. 4) Post fatigue exercise BEMS assessed in the same way as before. 5) Cool down – After the protocols and measurements the athlete was asked to take a stroll around the research venue for 5 minutes to achieve a cool down.

2.2.1. Back extensor muscles' strength (BEMS)

BEMS was assessed with a back and leg dynamometer calibrated from 0–300kgf (TKK 5002 BACK-A, Type 3 Takei Japan). Each athlete stood on the metallic plate base of the dynamometer with the feet held parallel, then bends forward slightly and grasp the bar to the thigh. The back was bent forward slightly at the hips while keeping the knees straight with the head held upright and looking straight ahead. Then, the athletes lifted steadily, keeping the knees straight and feet flat on the base of the dynamometer. At the completion of the test, the back was almost straight (Fig. 1). The athletes made three maximal efforts with two-minute rest interval and the highest reading (in kgf) was regarded as the BEMS.

2.2.2. Repetitive prone chest raise

The repetitive prone chest raise is a dynamic variant of the isometric prone chest raise test described by Ito et al. [25]. This protocol was done with the athlete lying prone on a gym mat with the upper limbs held alongside the trunk while the lower extremities were fixed by the examiner. The athlete was instructed to repetitively extend the trunk approximately 30°/s. The range of trunk motion during the protocol was standardized using a weight ball hanging from a frame. Once on extension, the athlete back touched the ball; he immediately goes back to the horizontal position on

Fig. 1.

the mat and the cycle continues. Each participant was encouraged to complete as many repetitions as possible; the protocol was terminated once the participant signaled that he was unable to perform further repetitions due to fatigue. However, uniform and standardized encouragement was given to all the athletes during the protocol.

The level of exertion of each athlete after the fatigue induction protocol was assessed using the 0–10 Borg's scale rating of perceived exertion (RPE) [7]. The torques generated from the pre-fatigue test and the post-fatigue test was compared. The difference between them was used to calculate the fatigue index i.e. the percentage change in maximum force after the fatigue induction protocol [1].

$$[(\text{pre-fatigue force – post-fatigue force})/ \\ \text{pre-fatigue force}] * 100$$

A pilot study was carried out prior to the main study to establish the test-retest reliability of BEMS for repeated measures same day and on different days among 20 athletes. The results of the Intra-class correlation coefficient (ICC) and standard error of measurement (SEM) indicate a high reliability ($p = 0.001$) for BEMS for repeated measures same day and on different days respectively (ICC $=$ 0.83, SEM $=$ 1.45 kgf and ICC $=$ 0.71, SEM $=$ 1.76 kgf; $p < 0.05$) respectively. The protocol was explained in details to each of the participants and the testing sequence was standardized. All testing procedures were performed by a single therapist.

2.3. Data analyses

Data were summarized using the descriptive statistics of mean and standard deviation. Inferential statistics involving independent t-test and Analysis of Variance (ANOVA) were also used. The data analyses were carried out using SPSS 13.0 version software (SPSS Inc., Chicago, IL, USA). The α-level was set at 0.05.

Table 1
Independent t-test comparison of the general characteristics and perceived exertion of the smoking and non smoking athletes

Variables	Smokers (52) Mean ± S.D	Non smokers (52) Mean ± S.D	t-cal	p-value
Age (yr)	23.1 ± 2.95	23.2 ± 2.37	−0.183	0.855
Height (m)	1.69 ± 0.07	1.75 ± 0.07	−3.701	0.005*
Weight (Kg)	66.0 ± 11.1	67.6 ± 13.0	−1.540	0.127
BMI (Kg/m^2)	23.2 ± 1.91	22.3 ± 1.89	2.421	0.017*
RPE	4.96 ± 1.38	2.29 ± 1.11	2.735	0.007*

*indicate significance.
Key: BMI = Body Mass Index; S.D = Standard Deviation; RPE = Rating of Perceived Exertion.

Table 2
Summary of the one – way analysis of variance and LSD post-hoc comparison of lumbar extension range of motion and BEMS before and after fatigue induction protocol among the smoking and non smoking

	Non smokers		Smokers			
	Pre-fatigue X ± SD	Post-fatigue X ± SD	Pre-fatigue X ± SD	Post-fatigue X ± SD	F-ratio	p-value
BEMS (Kg/f)	131.9 ± 23.5^a	134.6 ± 20.6^a	150.4 ± 15.2^b	133.6 ± 22.3^a	8.889	0.005*

^{a,b,c}For a particular variable, mode means with different superscripts are significantly ($p < 0.05$) different. Mode means with same superscripts are not significantly ($P < 0.05$) different.
*Indicates significance difference in pain intensity across different time periods.

3. Results

The general characteristics and perceived exertion of the smoking versus non-smoking athletes are presented in Table 1. The independent t-test comparison indicates that the smoking and the non-smoking athletes (23.1 ± 2.9 years vs. 23.2 ± 2.37 years) were age-matched. The smoking athletes take an average of 7 sticks of cigarettes daily. There was a significant difference ($p = 0.007$) in the Borg's scale rating of perceived exertion (RPE) between the smoking (4.96 ± 1.38) and non-smoking (2.29 ± 1.11) athletes.

Summary of the one – way ANOVA and LSD post-hoc comparison of BEMS before and after fatigue induction protocol among the smoking and non-smoking is presented in Table 2. Smoking athletes had higher pre-fatigue BEMS than their non-smoking counterparts. On fatigue induction, non-smoking athletes exhibited higher BEMS compared with their baseline value but was not statistically significant. However, a significant decrease in BEMS following fatigue induction was observed among the smoking athletes. The smoking athletes had a higher fatigue index (10.72%) compared with their non-smoking (5.06%) counterparts. The Pearson's product moment correlation analysis between pre-fatigue BEMS and the fatigue index was statistically significant ($r = 0.457$; $p = 0.000$) among all the participants. However, the relationship was only significant ($r = 0.523$; $p = 0.000$) among non-smoking athletes but not ($r = -0.0.84$; $p = 0.552$) among their smoking counterparts.

4. Discussion

Smoking is a major habit in developing countries. Smoking rate is reported to have increased as much as 50% in the developing countries, while it has been declining in the developed countries [58]. A similar high trend in smoking has been reported in Nigeria [24,40, 57]. The increasing rate of smoking among Nigerians can be linked to establishment of more tobacco industries in recent times, low cost of tobacco, lack of governmental control and policy on smoking, lack of smoking cessation programme and unrestricted media exposure on smoking. The number of cigarettes smoked per day among the smoking athletes in this study is within the range of 1–10, reported among smoking American college students [43].

Cigarette smoking among college students is reported to be a critical public health problem [42]. Some investigators reported that athletic capacity is diminished in smokers [3,6,29]. Unfortunately, research assessing BEMS in athletic populations is sparse. The purpose of this study was to compare back extensor muscle strength of smoking and non-smoking athletes following a fatigue protocol. The pre-fatigue induction BEMS of the smoking athletes was greater than that of non-smoking athletes. This result is at variance with previous reports from non-athletic populations that found higher baseline lumbar extensors strength among non-smoker compared with the smokers [17,31,49]. Furthermore, the finding on baseline BEMS in this study also contrasts the result of Al-Obaidi et al. [1] who found smokers to have lower lumbar extensor strength than the non-smokers.

The result of this study indicates that smoking athletes had higher rates of muscular fatiguability and decreased back extensor strength following back fatigue tasks. This was apparent as a higher perceived exertion and fatigue index was found among smoking athletes compared with their non-smoking counterparts. Also, a significant relationship was found between the pre-fatigue BEMS and fatigue index among the non-smoking athletes. Post-fatigue induction BEMS among non-smoker was higher than the baseline value but was not statistically significant; however, post-fatigue BEMS significantly decrease among smokers following fatigue induction. The result of this study is consistent with that of Al-Obaidi et al. [1] who reported that smokers had a significant reduction in strength after a fatigue challenge and that smoker had higher fatigue index than non-smokers. Our results are also in agreement with the findings of Kumar and Kumar [31] in a study on the effect of cigarette smoking on muscle strength and flexibility of athletes and confirmed a generalized reduction in strength among athletes who smoked compared to their non-smoking counterparts.

Increased muscular fatiguability in smokers is still poorly understood. It is probably multifactorial in origin, and there is strong evidence suggesting a link with chronic tissue hypoxia [3,16], nutritional abnormalities [4,13,16], and the development of oxidant/antioxidant imbalance [44,46,48]. Smoking is believed to be a mediating factor in the relation between muscle fatiguability and physical performance. Many studies have investigated the influence of cigarette smoking on exercise capacity [3,6,29,34]. Smokers are believed to have increased muscular fatiguability [49, 50], decreased muscular strength and endurance [5,8], higher rates of chronic and recurrent LBP [4,49], low cardiovascular fitness [3] and impaired work performance [55].

Early muscle fatigue predisposes the athlete to injury and affects optimal performance [23,30]. Krivickas and Fienberg [30] reported that lack of flexibility may produce early muscle fatigue or alter normal biomechanics of movement, predisposing to injury. When spinal muscles fatigue, their ability to produce a fast extensor movement is compromised along their ability to control trunk stability [38,39,56] and that may lead to incorrect spinal loading [49] and consequently LBP [47]. Decreased back muscles' strength is associated with poor performance and increased risk of injuries among athletes [9,21,32,54]. Potterfield and de Rosa [45] stated that lumbar extensors play a central role in maintaining spinal stability, erect posture, and in controlling the active range of the lumbar spine.

A potential limitation of the present study is the difficulty in ascertaining the patterns of smoking among the athletes as in most cases they were covert about it owing to some cultural and religious inhibition; hence snowballing technique, rather than randomization, was used to recruit some of the smoking athletes. It is therefore not unlikely that some of the athletes may have not disclosed their true smoking history. These limitations could be a focus of future studies in this area. We tried to minimize the effect of motivation and subjectivity of athletes' perceived limits of fatigue by recruiting elite athletes from the university team and by giving all the participants full information about the nature of the test and protocol; and also by giving uniform and standardized encouragement during testing and protocol.

5. Conclusions

Smoking athletes have higher rates of muscular fatiguability and decreased back strength following back extensors tasks. Smoking is associated with increased muscle fatiguability and impairment of back strength and mobility in athletes. Smoking athletes may lack sufficient back strength for optimal performance and may be at risk for injury.

References

[1] S.M. Al-Obaidi, J. Anthony, N. Al-Shuwai and E. Dean, Differences in back extensor strength between smokers and non-smokers with and without low back pain, *Journal of Orthopaedic and Sports Physical Therapy* **34**(5) (2004), 254–260.

[2] J.J. Barendregt, L. Bonneux and P.J. van der Maas, The health care costs of smoking, *New England Journal of Medicine* **337**(15) (1997), 1052–1057.

[3] C.M. Bernaards, J.W.R. Twisk, W. Van Mechelen, J. Snel and H.C.G. Kemper, A longitudinal study on smoking in relationship to fitness and heart rate response, *Medicine and Science in Sports Exercise* **35** (2003), 793–800.

[4] . F. Biering-Sorensen and C. Thomson, Medical, social and occupational history as risk indicators for low back trouble in a general population, *Spine* **11** (1986), 720–725.

[5] F. Biering-Sørensen, A prospective study of low back pain in a general population, *Scandinavian Journal of Rehabilitation Medicine* **15** (1983), 81–88.

[6] G. Bolinder, A. Norén, J. Wahren and U. De Faire, Long-term use of smokeless tobacco and physical performance in middle-aged men, *European Journal of Clinical Investiagtion* **27** (1997), 427–433.

[7] G.A. Borg, Perceived exertion as an indicator of somatic stress, *Scandinavian Journal of Rehabilitation Medicine* **23** (1970), 92–98.

[8] A. Burdorf, M. Van Riel and C. Snijders, Trunk muscle strength measurement and prediction of low back pain among workers, *Clinical Biomechanics* **7** (1992), 55–58.

[9] M.A. Clark, Core competency underlies functional rehabilitation, *Biomechanics* **7**(2) (2000), 67–73.

[10] N.E. Collishaw and A.D. Lopez, Prevalence of cigarette smoking in developing countries, *Editorial – Tob Control* **4** (1995), 327.

[11] T.L. Conway and T.A. Cronan, Smoking, exercise, and physical fitness, *Preventive Medicine* **21, 6**, 723–734.

[12] J.M. Cox and K.K. Trier, Exercise and smoking habits in patients with and without low back and leg pain, *Journal of Manipulative and Physiological Therapeutics* **10**(5) (1987), 239–245.

[13] R.A. Deyo and J.E. Bass, Lifestyle and low back pain: the influence of smoking and obesity, *Spine* **14**(5) (1989), 501–506.

[14] W. Eriksen, B. Natvig and D. Bruunsgaard, Smoking, heavy physical work and low back pain: A four-year prospective study, *Occupational Medicine* **49** (1999), 155–160

[15] M.O. Erkintalo, J.J. Salminen, A.M. Alanen, H.E. Paajanen and M.J. Kormano, Development of degenerative changes in the lumbar intravertebral disk: results of a prospective MR imaging study in adolescents with and without low-back pain, *Radiology* **196**(2), 529–533.

[16] E. Ernst, Smoking, a cause of back trouble? *British Journal of Rheumatology* **32** (1993), 239–242.

[17] . D.E. Feldman, M. Rossignol and I. Shrier, A risk factor for development of low back pain in adolescents, *Spine* **24**(23) (1999), 24–95.

[18] M.M. Finkelstein, Back pain and parenthood, *Occupation and Environmental Medicine* **52**(1) (1995), 51–53.

[19] J.W. Frymoyer, M.H. Pope and J.H. Clements, Risk factors in low back pain, *Journal of Bone and Joint Surgery [Am]* **65A** (1983), 213.

[20] M.S. Goldberg, S.C. Scott and N.E. Mayo, A review of the association between cigarette smoking and the development of nonspecific back pain and related outcomes, *Spine* **25**(8) (2000), 995–1011.

[21] A. Hedrick, Training the trunk for improved athletic performance, *Strength and Conditioning Journal* **22**(3) (2000), 50–61.

[22] K.A. Hollenbach, E Barrett-Connor, S.L. Edelstein and T. Holbrook, Cigarette smoking and bone mineral density in older men and women, *American Journal of Public Health* **83** (1993), 1265–1270.

[23] P.J. Holt, A.M. Bull, P.M. Cashman and A.H. McGregor, Kinematics of spinal motion during prolonged rowing, *International Journal of Sports Medicine* **24** (2003), 597–602.

[24] C.C. Ibeh and P.U. Ele, Prevalence of cigarette smoking in young Nigerian females, *African Journal of Medicine and Medical Sciences* **32**(4) (2003), 335–338.

[25] T. Ito, O. Shirado, H. Suzuki, M. Takahashi, K. Kaneda and T.E. Strax, Lumbar trunk muscle endurance testing: an inexpensive alternative to a machine for evaluation, *Archive of Physical Medicine and Rehabilitation* **77** (1996), 75–79.

[26] P.V. Karpovich and J.H. Creighton, Tobacco Smoking and Physical Performance, *Applied Physiology* **3**(10) (1951), 616–621.

[27] J.L. Kelsey, P.B. Githens, A.A. White, T.R. Holford, S.D. Walter, T. O'Connor, A.M. Ostfeld, U. Weil, W.O. Southwick and J.A. Calogero, An epidemiologic study of lifting and twisting on the job and risk for acute pro-lapsed lumbar intervertebral disc, *Journal of Orthopaedic Research* **2**(1) (1984), 61–66.

[28] J.L. Kelsey and A.M. Ostfeld, An epidemiological study of acute herniated lumbar intervertebral discs, *Rheumatology and Rehabilitation* **14** (1975), 144–159.

[29] Y. Kobayashi, T. Takeuchi, T. Hosoi and J.A. Loeppky, Effects of Habitual Smoking on Cardiorespiratory Responses to Submaximal Exercise, *Journal of Physiological, Anthropology and Applied Human Science* **23** (2004), 163–169.

[30] L.S. Krivickas and J.H. Fienberg, Lower extremity injuries in college athletes: Relation between ligamentous laxity and lower extremity muscle tightness, *Archive of Physical Medicine and Rehabilitation* **77** (1996), 1139–1143.

[31] P. Kumar and N.V. Kumar, Effect of cigarette smoking on muscle strength and flexibility of athletes, *Indian Journal of Experimental Biology* **36** (1998), 114–1146.

[32] C.L. Lanning, T.L. Uhl, C.L. Ingram, C.G. Mattacola, T. English and S. Newsom, Baseline Values of Trunk Endurance and Hip Strength in Collegiate Athletes, *Journal of Athletic Training* **41**(4) (2006), 427–434.

[33] C. Leboeuf-Yde, Smoking and low back pain. A systematic literature review of 41 journal articles reporting 47 epidemiologic studies. *Spine* **24** (1999), 1463–1470.

[34] A.R. Morton and E.V. Holmik, The effects of cigarette smoking on maximal oxygen consumption and selected physiological responses of elite sportsmen, *European Journal of Applied Physiology and Occupational Physiology* **53** (1985), 348–352.

[35] P. McDonough and R.J. Moffatt, Smoking-induced elevations in blood carboxyhaemoglobin levels. Effect on maximal oxygen uptake, *Sports Medicine* **27**(5) (1999), 275–283.

[36] A.S. Muula and L. Mpabulungi, Cigarette smoking prevalence among school-going adolescents in two African capital cities: Kampala Uganda and Lilongwe Malawi, *Afr Health Sci* **7**(1) (2007), 45–49.

[37] J.P. Nelson, Youth smoking prevalence in developing countries: effect of advertising bans, *Applied Economics Letters* **10**(13) (2003), 805–811.

[38] M.M. Panjabi, Clinical spinal instability and low back pain, *Journal of Electromyography and Kinesiology* **13**(4) (2003), 371–379.

[39] M. Parnianpour, M. Nordin, N. Kahanovitz and V. Frankel, 1998 Volvo award in biomechanics: The triaxial coupling of torque generation of trunk muscles during isometric exertions and the effect of fatiguing isoinertial movements on the motor output and movement pattern, *Spine* **13**(9) (1998), 982–992.

[40] D.O. Olufemi, O.B. Abdulfatai, D. Ali, S.K. Fatai and I.M. Batulu, Epidemiology of Tobacco Smoking Among Adults Population In North-East Nigeria, *The Internet Journal of Epidemiology* **6**(1) (2008).

[41] N. Ortego-Centeno, M. Munoz-Torrez, J. Hernandez-Quero, A. Jurado-Duce and J. de la Higuera Torrez-Puchol, *Bone mineral density*, sex steroids, and mineral metabolism in

premenopausal smokers, *Calcified Tissue International* **55** (1994), 403–407.

[42] F. Patterson, C. Lerman, V.G Kaufmann and G.A. Neuner, Prevalence and Predictors of Transitions in smoking behavior among college students, *Health Psychology* **23**(2) (2004), 168–177.

[43] F. Patterson, C. Lerman, V. G Kaufmann, G.A. Neuner and J. Audrain-McGovern, Cigarette Smoking Practices Among American College Students: Review and Future Directions. Journal of American College, *Health Issue* **52**(5) (2004), 203–212.

[44] S. Petruzzelli, L.M. Tavanti, N. Pulera, E. Fornai, R. Puntoni, A. Celi and C. Giuntini, Effects of nicotine replacement therapy on markers of oxidative stress in cigarette smokers enrolled in a smoking cessation program, *Nicotine and Tobcco Research* **2** (2000), 313–315.

[45] J.A. Potterfield and C. de Rosa, Mechanical low back pain. Perspective in functional anatomy. 2nd Edition, Saunders, Philadelphia. 1997, 53–119.

[46] I. Rahman, D. Morrison, K. Donaldson and W. MacNee, Systemic oxidative stress in asthma, COPD, and smokers, *American Journal of Respiratory and Critical Care Medicine* **1**(54) (1996), 1055–1060.

[47] S.H. Roy, C.J. Deluca and D.A. Casavant, Lumbar muscle fatigue and chronic low back pain, *Spine* **14** (1989), 992–1001.

[48] P. Rytila, T. Rehn, H. Ilumets, A. Rouhos, A. Sovijarvi, M. Myllarniemi and V.L. Kinnula, Increased oxidative stress in asymptomatic current chronic smokers and GOLD stage 0 COPD, *Respiratory Research* **7** (2006), 69.

[49] A. Saud, A.A. Baker and A. Nadia, Fatigue susceptibility of the lumbar extensors muscles among smokers, *Physiotherapy* **89**(4) (2003), 238–248.

[50] J. Scott, The effects of smoking on athletes. Smoking is extremely detrimental for athletes. General nutrition and health. http://www.cdc.gov/tobacco/educational_materials/yuthfax1.htm. (Last assessed October, 18th 2009).

[51] A.J. Silman, J. Newman and A.J. Macgregor, Cigarette smoking increases the risk of rheumatoid arthritis: results from a nationwide study of disease discordant twins, *Arthritis Rheum* **39**(5) (1996), 732–735.

[52] H. Svensson and G.B.J. Andersson, Low- back pain in 40- to 47-year old men: work history and work environment factors, *Spine* **8** (1983), 272–276.

[53] H.-O. Svensson, A. Vedin, C. Wilhelmsson and G.B.J. Andersson, Low-back pain in relation to other diseases and cardiovascular risk factors, *Spine* **8** (1983), 277–285.

[54] A.D. Tyson, The bridge, *Strength and Conditioning* **22**(6) (2000), 46.

[55] M. Unverdorben, A. der Bijl, L. Potgieter, Q. Liang and B.H. Meyer, Roethig HJ. Effects of levels of cigarette smoke exposure on symptom-limited spiroergometry, *Preventive Cardiology* **10** (2007), 83–91.

[56] J.H. Van Diien and P. Heijbolm, Reproducibility of isometric trunk extension torque, trunk extensor endurance. And related electromyographic parameters in the context of their clinical applicability, *J Orthop Res* **14** (1996), 139–143.

[57] World Health Organization. Prevalence of tobacco smoking in Nigeria. Geneva, WHO; 2001. http://www.who.int/tobacco/en/.

[58] J.J. Yu and D.R. Shopland, Cigarette smoking behaviour and consumption characteristics for the Asia – Pacific region, *World smoking and Health* **14** (1989), 7–9.