Evaluation of the influence of low and high heel shoes on erector spine muscle bioelectrical activity assessed at baseline and during movement

Ocena wpływu obuwia na niskich i na wysokich obcasach na aktywność bioelektryczną mięśnia prostownika kręgosłupa ocenianą w spoczynku i podczas ruchu

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Key words
surface electromyography, lumbar spine, heel shoes, sequence test

Abstract
Introduction: Back pain due to the wearing of high heel shoes may result from increased erector spine activity and also from higher proximal ground reaction forces or center of body mass dislocation.
Aim: The assessment of changes in the erector spine muscle due to the non-physiological foot position in low and high heel shoes.
Material and Methods: In 31 women aged 20-25 years (height 167,6 ±5.8 cm; weight 60,35 ±6,49 kg) without back pain, the bioelectrical activity of the erector spine muscle was assessed. A lumbar spine sequence test was performed without shoes and in low (4 cm) and in high (10 cm) heel shoes. Muscle activity on the right and left sides was evaluated at baseline and during movement. The mean and peak signal value were compared between 3 measurements (without, in low and in high heel shoes).
Results: A statistically significant increase in erector spine activity was observed in Trunk Flexion ($p<0,05$) and during Flexion-Relaxation Position ($p<0,05$) when wearing high hell shoes. Those variables correlated significantly in all 3 measurements (without, in low and in high heel shoes). A significant correlation was noted between the Flexion-Relaxation Position and Extension/Flexion Ratio ($p<0,05$). Bioelectrical erector spine activity differed significantly during Rotation Right and Rotation Left in all 3 measurements respectively ($p<0,05$).
Conclusion: The prolonged wearing of shoes with stiletto type low and high heels by individuals without back pain is not safe for their spine and may lead to chronic paraspinal muscle fatigue.

Słowa kluczowe
elektromiografia powierzchniowa, kręgosłup lędźwiowy, obcasy, test sekwencyjny

Streszczenie
Wstęp: Dolegliwości bólowe dolnego odcinka kręgosłupa w następstwie używania butów na wysokich obcasach mogą być spowodowane zwiększoną aktywnością prostownika kręgosłupa, jak również przez zwiększenie działających na proksymalne odcinki kończyn sił reakcji podłoża, czy też przesunięciem środka ciężkości ciała.
Cel pracy: Celem pracy była ocena zmian w aktywności bioelektrycznej mięśni przykręgosłupowych spowodowanych niefizjologicznym ułożeniem stopy w obuwiu na niskich i na wysokich obcasach.
Materiał i Metoda: U 31 kobiet w wieku 20-25 lat (wzrost 167,6 ±5,8 cm; waga 60,35 ±6,49 kg), bez dolegliwości bólowych badano aktywność bioelektryczną mięśnia prostownika kręgosłupa. Test sekwencyjny dla odcinka lędźwiowego kręgosłupa przeprowadzono bez obuwia, oraz w butach typu szpilki na obcasie o wysokości 4 cm (obcas niski) i na obcasie o wysokości 10 cm (obcas wysoki). Oceniano pracę mięśni po prawej i lewej stronie, zarówno w spoczynku, jak i podczas ruchu. Porównano średnią i szczytową wartość sygnału pomiędzy pomiarami bez butów, w butach na niskich i na wysokich obcasach.
Wyniki: Obcas wysoki w sposób statystycznie istotny zwiększał aktywność prostownika kręgosłupa podczas zgięcia do przodu w płaszczyźnie strzałkowej ($p<0,05$), oraz w pozycji maksymalnego zgięcia do przodu ($p<0,05$). Parametry te korelowały ze sobą w sposób istotny statystycznie, zarówno w pomiarze bez butów, jak i w pomiarach na niskich i na wysokich obcasach. Statystycznie

The letters indicate the authors' contribution to the paper: A – research project; B – data collection; C – statistical analysis; D – data interpretation; E – work on manuscript; F – literature search; G – funds procurement

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istotną zależność zaobserwowano także pomiędzy współczynnikiem wyprostno-zgięciowym i aktywnością prostownika kręgosłupa podczas zgięcia w płaszczyźnie strzałkowej. Stwierdzono statystycznie istotne różnice w aktywności mięśni prostowników kręgosłupa podczas ruchu rotacji w prawo i w lewo we wszystkich 3 pomiarach (p<0,05).
Wnioski: Długotrwałe używanie obuwia na niskich i na wysokich obcasach typu szpilka przez osoby bez dolegliwości bólowych w odcinku lędźwiowym nie jest bezpieczne dla kręgosłupa i może prowadzić do przewlekłego zmęczenia tych mięśni.

INTRODUCTION

Troublesome pain in the area of the lumbar vertebra constitute some of the most often cited causes of discomfort in western societies, and have even been considered to a disease of our civilisation[1]. Around 60 to 85% of the inhabitants of highly developed countries experience pain in the lumbar vertebra as a result of various factors[2]. One of the factors considered to lead to a predisposition for such complaints is the wearing of footwear with high heels[1,3]. However the relevant raising of the heel by such footwear may act as equally destructively for the spine[3,4], as it may, if the right conditions are maintained, be helpful in the treatment of these very complaints [4-6].

Lee et al.[3] examined a group of 200 women, who regularly wore high-heeled shoes and claimed that 58% of them experienced pain when wearing them. One of the possible factors considered was the increased value in the reaction forces of the base when walking in high-heeled shoes when compared to walking in trainers with a flat heel[7,8].

A slight bilateral elevation of the heel through an insert to the footwear is recommended by doctors as a method for the treatment of lumbar vertebra pains. However, there is little research that objectively confirms the effectiveness of this method, while advice on this type of therapy results more from everyday practical observations and belief in its usefulness[1].

The beneficial pain reducing effect of heel-raising inserts observed by certain authors may also be explained by the changes in the activeness of the paravertebral muscles[1,3]. Bird et al.[1] have noted within healthy individuals without lumbar vertebra pain the influence, of the raising of the foot equally by means of a varied height of insert to the footwear, on the activity of the spine's extensor muscles and the middle gluteal muscle. They noted that the bilateral raising of the heel by an insert of a height of 20 mm causes a significantly earlier moment in the activity of the spine's extensor muscles on the side of the limb which is in the phase of raising the heel, confirming the earlier reports of other researchers[9-11]. Equally Lee et al.[3] noted in healthy individuals a significant growth in the amplitude of the signal of the surface electromyography of the spinal extensor muscle during the contact of the heel with the base while walking in footwear with heels 45 mm and 80 mm when compared to walking without footwear.

It is considered that pain experienced in the lower part of the spine as a consequence of wearing shoes with high heels could be caused also by factors such as the increase in the reaction forces of the base acting on the proximal sections of the limbs, or the shift in the centre of the body's mass (COM) forwards and upwards[3,12]. Such a shift in the COM may result in an earlier and greater activity of the spinal extensor which has the purpose of maintaining the appropriate balance in the area of the pelvis and the lumbar vertebra during walking. A stronger contraction of the spinal extensor may make the maintaining of the appropriate angle of the lumbar lordosis easier and with it the repositions of the COM towards the rear in the direction of the physiological position (equalising frontally the shift of COM caused by the high heel)[1,5]. However, it results from this research that the organism may compensate, through the increased activity of the paravertebral muscles resulting from the raising of the heel by the shoe heel, for the shift in COM only at a certain height and that highly raised heels result in an excessive burden at the level of the IV lumbar vertebra[12].

There is described in the relevant literature the phenomenon of reducing the activity of the paravertebral muscles observed in the final phase of bending the spine to the fore in the sagittal plane, which is termed the phenomenon of bending – loosening[13-15]. This natural disconnecting of the spinal extensor occurring in this position does not occur in individuals with painful problems in a section of the lumbar vertebra[16].

One of the methods for the normalisation of the sEMG is the reference of its value for a given muscle to the value obtained for that muscle during its maximum isometric contraction (MVC)[17]. However, in patients with painful disorders of a vertebra section the Extension-Flexion Ratio is proposed as a method for normalisation[18].

The aim of the work was the evaluation of changes in the bioelectrical activity of paravertebral muscles brought about by the non-physiological position of the foot by footwear with low and high heels. The following research questions were asked:

Does a change in the foot position caused by footwear with low and/or high heels in healthy individuals (without pain in the area of the lumbar section of the spine) cause a significant difference in the bioelectric activity of the spinal extensor muscle at rest and during movement?

Can a significant difference be observed in the value of the Extension-Flexion Ratio between the measurement conducted without footwear and in footwear with heels?

Can the use of footwear with low and/or high heels on the part of individuals without painful problems in the section of the lumbar spine be a potential factor in the overloading of its structure and the cause of pathological changes in the future?

MATERIALS AND RESEARCH METHODS

Research group description

31 women aged 20-25 took part in the research (body height 167.6 ±5.8

cm; body mass 60.35 ±6.49 kg), without problems with back pains in the lumbar vertebra either in the past or currently. Those with confirmed overloading changes in the lumbar vertebra or with other pathologies which could have affected the course and results of the research were not qualified for participation. All those tested wore high-heeled shoes occasionally, not more frequently than once a month.

All measurements were taken threefold for each of those tested for each visit. The test was conducted without footwear, in shoes of the stiletto heeled type with 4 cm heels (low heels) and in shoes of the stiletto heeled type with a height of 10 cm (high heels). The heels had a base of 1 cm^2.

Before measurements commenced all the participants were informed in detail about their course and gave their consent to participate in the testing. Permission was obtained from the bioethics commission for the conducting of the research.

Research

Research into the electromyographic activeness of the extensor muscle was conducted by means of the electromyograph *POCKET EMG (BTS, Bioengineering)*. The registration and analysis of the sEMG signal was conducted with the aid of the *Smart Analyzer (BTS, Bioengineering)* program.

The skin in the place where the electrode was attached was degreased with alcohol. The surface electrodes (Ag/AgCl) *(BIO LEAD-LOK)* were attached along the direction of the position of the muscle fibres on the belly of the spinal extensor muscle at the height of the third lumbar vertebra on the right and left side 2 cm from and along the spine. The research was conducted in accordance with the guidelines of the SENIAM project[19].

Before the test the person examined carried out each of its elements 2-3 times with the aim of becoming fully acquainted with the nature of the movement made.

The sEMG sequential test for the lumbar vertebra section[20,21] (Figure 1).

1. Phase I – posture test,
   a. The person tested stands in a comfortable and natural position for 5 seconds;
2. Phase II – bending of the torso/return to a neutral position,
   b. The person tested carries out a full torso bend forward – 5 seconds,
   c. For 5 seconds she remains in a position of maximum bending loosely hanging (bending–relaxing),
   d. Return to a neutral position - 5 seconds;
3. Phase III – straightening up/return to a neutral position,
   a. The person tested stands in a comfortable and natural position for 3 seconds
   b. The person tested carries out a straightening out of the torso backwards – 5 seconds
   c. Return to a neutral position - 5 seconds
4. Phase IV – rotation of the torso to the right and the left
   a. The person tested carries out a rotation of the torso to the right and back to a neutral position – 7-8 seconds
   b. The person tested carries out rotation of the torso to the left and back to a neutral position – 7-8 seconds
5. Phase V – side bending of the torso to the right and the left
   a. The tested person carries out side bending of the torso to the right and back to the neutral position – 7-8 seconds
   b. The person tested carries out side bending of the torso to the left and back to the neutral position – 7-8 seconds

Parameter evaluation

1. The *mean* and the *peak* value of the sEMG (mV) signal – the work of the muscle to the right and left was analysed both at rest as during each of the moves carried out in the various phases of the test (Figure 2). The values obtained for the vari-

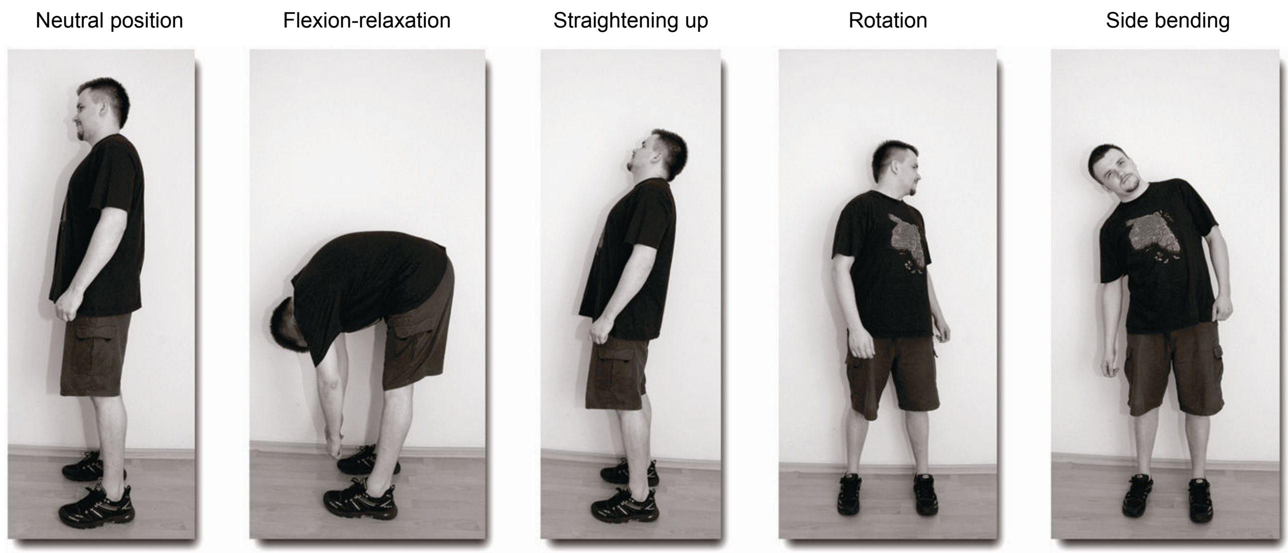

Figure 1
Lumbar sEMG sequence test

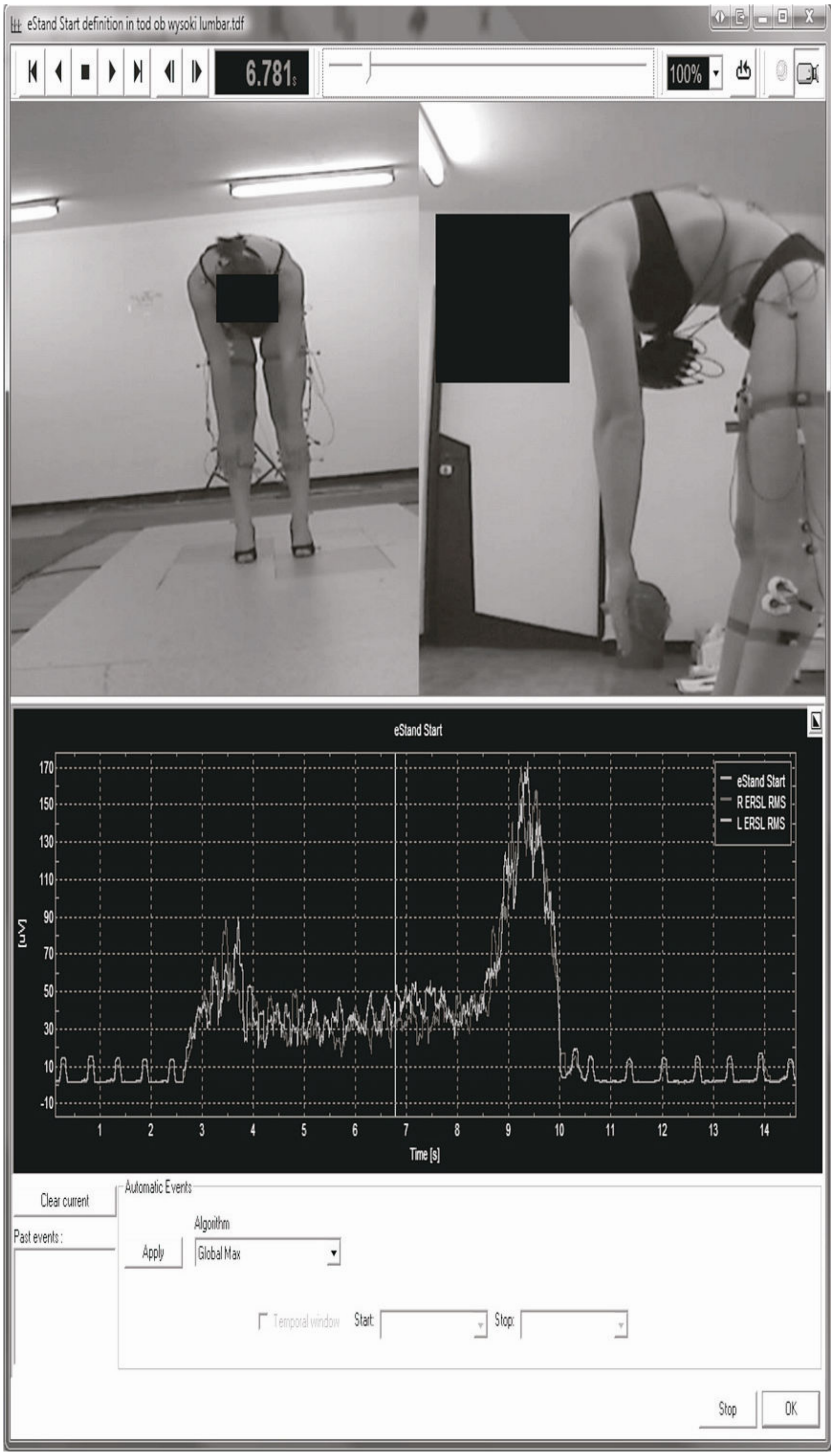

Figure 2

Erector spine bioelectrical activity during Trunk Flexion, the Flexion-Relaxation Position and return to neutral

ous phases of the test were compared between the measurement conducted without footwear and that for footwear with a low and a high heel.

2. The mean and peak value of the sEMG signal was analysed for the following test phases:

– Postural Test – free standing position;
– Flexion Relaxation Position – position of maximum bending forward in the sagittal plane;
– Sagittal Extension – extension backwards in the sagittal plane;
– Trunk Flexion – bending movement forward (excentric work of the spinal extensor) (comparison of muscle activity on the right and left side);
– Return to Neutral – return movement to the starting position (concentric work of the spinal extensor) (comparison of muscle activity on the right and left side)
– Extension/Flexion Ratio – the value of the extension-flexion ratio measured during the II phase of the test;
– Rotation Right – rotation to the right in the transverse plane (comparison of muscle activity on the right and left side);
– Rotation Left – rotation to the left in the transverse plane (comparison of muscle activity on the right and left side);
– Lateral Flexion Right – bending to the right in the frontal plane (comparison of muscle activity on the right and left side);
– Lateral Flexion Left - bending to the left in the frontal plane (comparison of muscle activity on the right and left side).

The extension/flexion ratio (Figure 3) determined for the extensor muscles of the spine during the correct bending forward should equal about 2,0. We calculate this ration by dividing the peak value of the sEMG amplitude signal measured during the movement back from the bend to the starting position (the concentric work of the muscle) by the peak value of the amplitude during the movement of the bend forward (excentric work).

The value of the extension/flexion ratio lower than 1,8 indicates the disturbed working of the spinal extensor, while the reduction of its value results from the fact that in pathological states of the lumbar vertebra the peak value of the amplitude during concentric work diminishes while during excentric work it increases[14,20].

Data analysis

The statistical analysis was conducted using the program *STATISTICA Pl*. The *ANOVA* test was employed, distribution with repeating measurements, for the evaluation of

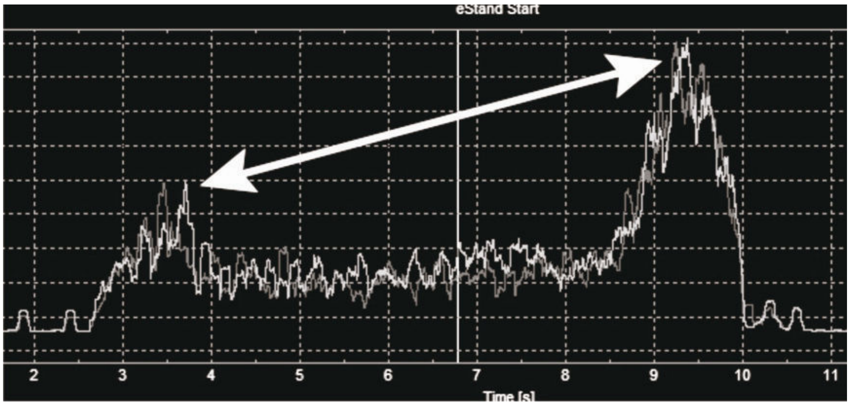

Figure 3

Lumbar spine Extension - Flexion Ratio

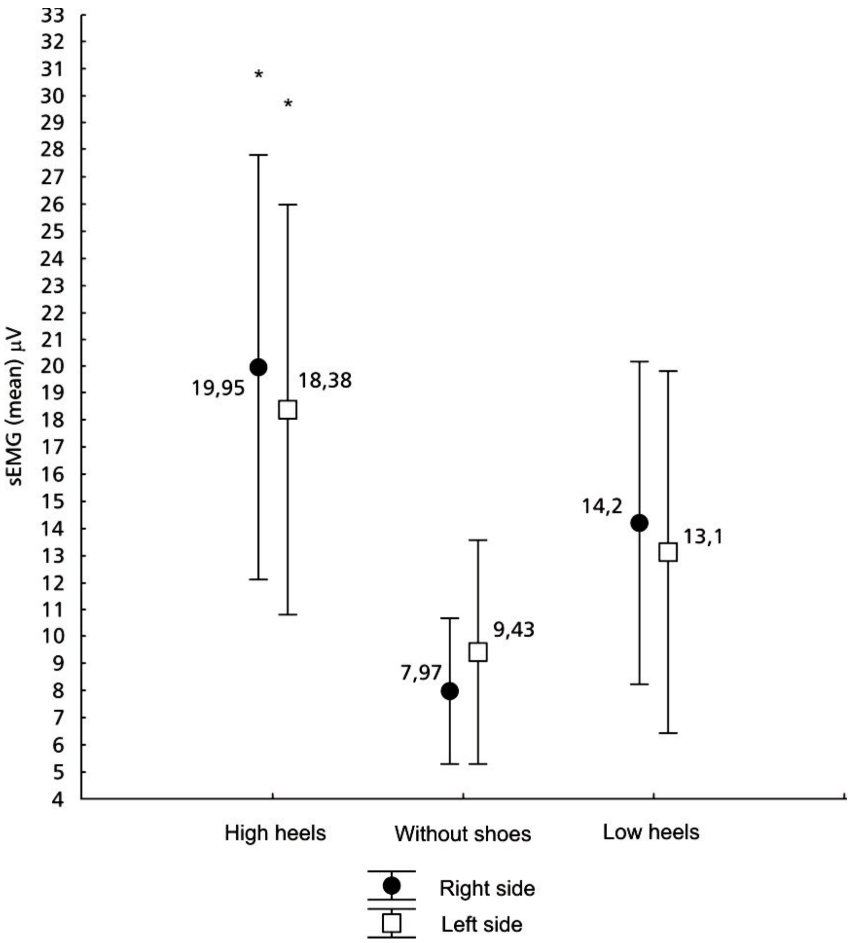

Figure 4

Mean value of erector spine activity (mean sEMG) during Flexion–Relaxation Position for 3 measurements respectively. Values are expressed as a mean ± SD; * p<0,05

the significance in the differences of the tested traits from amongst the measurement without footwear, in footwear with a low heel and with a high heel. The differences were considered as statistically significant if the level of test probability was lower than the assumed level of significance ($p<0,05$). The coefficient of the Pearson line correlation (r) was used in the analysis of the force and direction of the dependence between the selected variables.

Results

The testing of the muscle activity in the area of the spinal extensor did not display statistically significant differences between the measurement conducted without footwear, in footwear with low heels and with high heels both in a free standing position (Postural Test) ($p>0.05$), as during extension backwards in the sagittal plane (Sagittal Extension) ($p>0.05$).

In the position of maximum forward bending in the sagittal plane when the spinal extensor should be completely relaxed (Flexion/Relaxation Position), there were not noted statistically significant differences between the measurement without footwear and in footwear with a low heel ($p>0.05$). A low heel did not cause a significantly greater activeness of the spinal extensor. The high heel, however, in a statistically significant way increased the activeness of the spinal extensor (Figure 4).

A statistically significant difference was observed in the activeness of the spinal extensor during bending forward (Trunk Flexion) between the measurement taken without footwear and in footwear with a high heel (Figure 5).

There appeared a high statistically significant correlation between the activeness of the spinal extensor during bending forward (Trunk Flexion) and the activeness of the spinal extensor in the position of a total bend forward (Flexion-Relaxation Position). The dependence between these parameters was equally observed in the measurement without footwear as in the measurements for footwear with low and high heels (the greater the activeness of the spinal extensor during movement was, the greater was its activeness during the phase of relaxation at full bend) (Table 1).

There was an absence during the return movement from bending to the

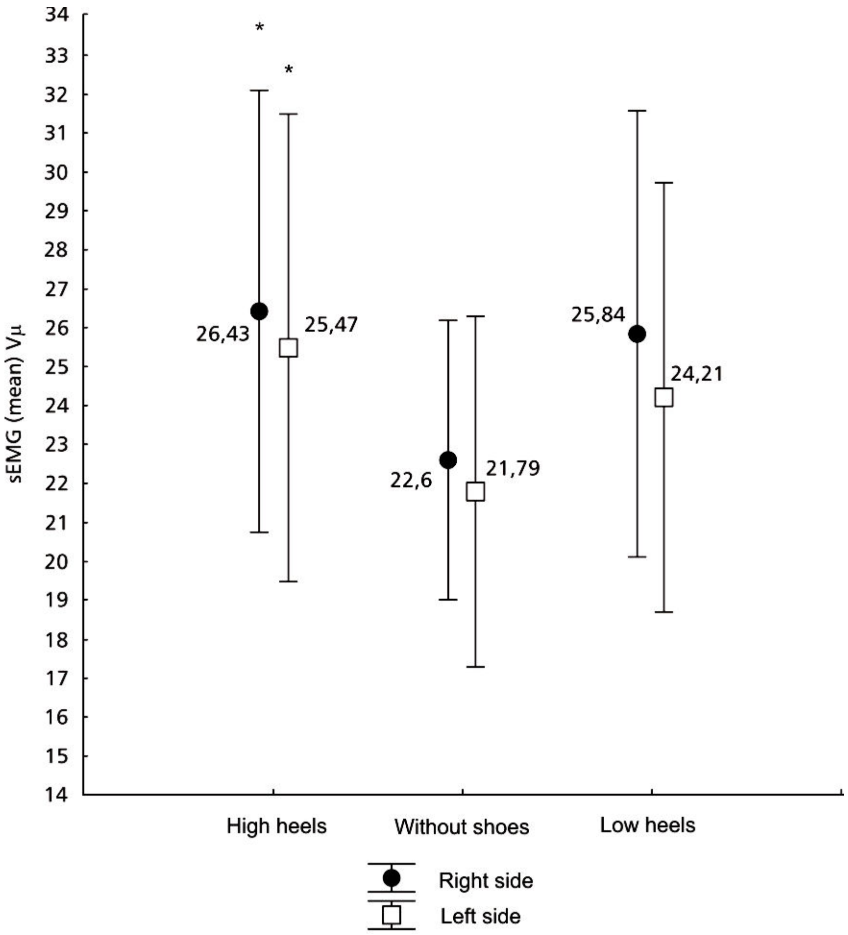

Figure 5

Mean value of erector spine activity (mean sEMG) during Trunk Flexion for 3 measurements respectively. Values are expressed as a mean ± SD; * p<0,05

starting position (Return to Neutral) of significant differences between the individual measurements (p>0.05).

There was equally not noted any statistically significant differences between the measurement without footwear and in footwear with low and high heels in the area of the extension/flexion ratio (p>0.05), as equally this coefficient did not correlate in a statistically significant way with the activeness of the spinal extensor during relaxation at the maximum bend forward (Flexion-Relaxation Position) (p>0.05).

A statistically significant dependence was observed, however, between the Extension/Flexion Ratio and the Trunk Flexion. (Table 2).

There was observed a statistically significant difference in the activeness of the spinal extensor muscles during rotational movement to the right and left (Rotation Right and Rotation Left) both during the measurement without footwear as equally in footwear with low and high heels (Figure 6 and 7).

In the lateral flexion in the frontal plane to the right and left (Lateral Flexion Right and Lateral Flexion Left) footwear with low and high heels did not statistically significantly change the activeness of the spinal extensor (p>0,05).

Discussion

The most important information resulting from tests conducted is that footwear of the stiletto type of a height of 10 cm increases in a significant way the activeness of the spinal extensor muscle, something that may be observed both during the movement of forward flexion in the sagittal plane as equally in the position of maximum bending when the spinal extensor should be inactive. Excessive activity in the area of the tested paravertebral was noted equally during rotational movements in the transverse plane as well as in the measurement in low and high heels. This may suggest that heels of the stiletto type regardless of their height excessively burden the paravertebral muscles during movements carried out in an unstable position, an example of which is rotation in the transverse plane.

Increased activeness of the spinal extensor as a consequence of the lifting of the heel of the foot by the heel of a shoe has also been observed by other researchers in their own tests [1,3,22]. Barton et al.[1] observed in individuals without pain problems in the lumbar section a significant increase in the amplitude of the sEMG signal for the spinal extensor evaluated at the moment of heel contact with the base during walking in footwear on 45 mm and 80 mm heels when compared to walking without footwear.

Other researchers have suggested[7,8] that the earlier activeness of the spinal extensor observed in individuals without painful symptoms of the lumbar spine who subsequently apply inserts to raise the heel could be a compensatory mechanism for the increased forces reaction of the base in shoes with a heel. Additionally a greater and earlier activeness in these muscles was noted when those tested walked upon a hard base[22]. Hence therefore the earlier activeness of the spinal extensor in a situation whereby the raising of the heel of the foot by the shoe heel may be brought about by a decreased ability in the absorption of impact jolts by the foot and increased value of the forces of reaction in the base in the proximal sections of the limb and in the section of the lumbar spine[7,8]. While the limitation in the possibility to absorb impact jolts may be caused by the reduced pronation of the foot in the lower ankle joint[12], as well as being a result of positioning the foot in a greater sole arch and supination, intensified by the internal rotation of the tibia [23] observed at the moment of contact of the foot with the ground. Equally the correct pronation in the lower ankle joint as equally the appropriate internal rotation of the tibia

Table 1

Correlation between Trunk Flexion and Flexion–Relaxation Position for the right and left side respectively

	Without shoes	High heels	Low heels
Right side	r = 0.87*	r = 0.47*	r = 0.76*
Left side	r = 0.88*	r = 0.78*	r = 0.80*

r – coefficient of the Pearson line correlation; * - p<0.05

Table 2

Correlation between Trunk Flexion and Extension–Flexion Ratio for the right and left side respectively

	Without shoes	High heels	Low heels
Right side	r = -0.41*	r = -0.58*	r = -0.49*
Left side	r = -0.60*	r = -0.56*	r = -0.42*

r – coefficient of the Pearson line correlation; * - p<0.05

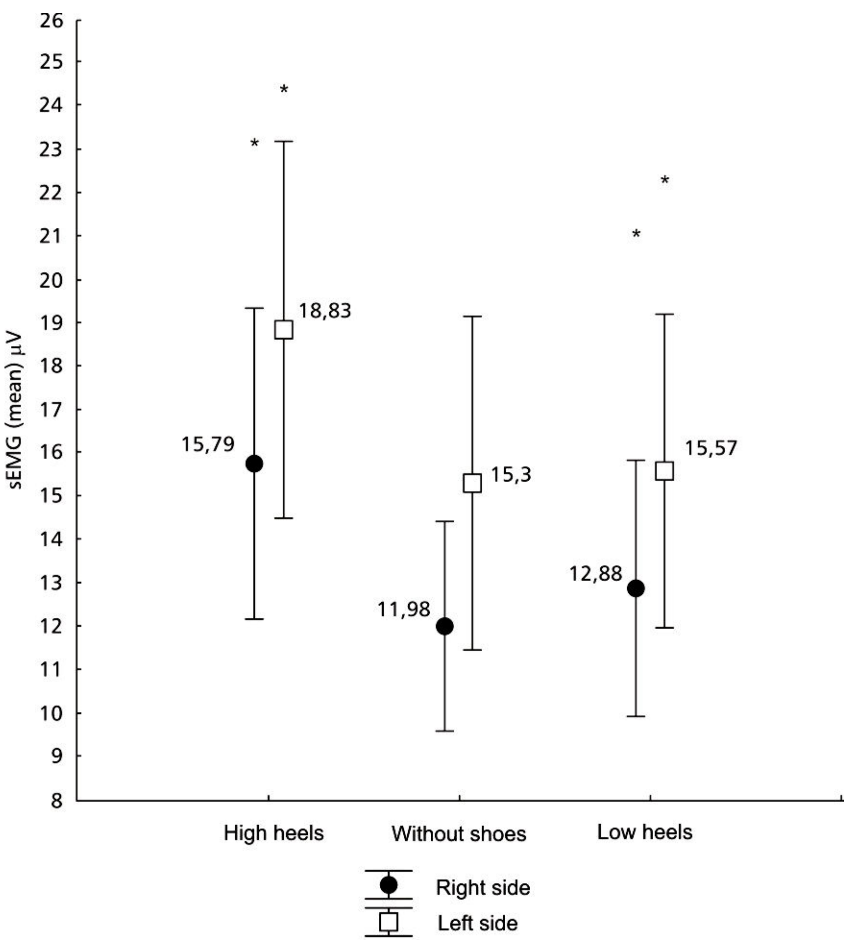

Figure 6

Mean value of erector spine activity (mean sEMG) during Rotation Right for 3 measurements respectively. Values are expressed as a mean ± SD; * p<0,05

are necessary conditions for the correct absorption of impact jolts through the plantar aponeurosis and of the correct work of the excentric muscle supinating the foot[24].

An increase in the activeness of the spinal extensor as a consequence of raising the foot through the shoe heel may have equally other causes independent of changes in the range of the forces of ground reaction. The shifting of COM to the fore and upwards may be considered as such, this results in an earlier and greater activeness of the spinal extensor with the aim of maintaining the correct balance in the area of the pelvis and the lumbar spine during walking[3,12]. It is considered that a stronger contraction of the spinal extensor may ease the placing of the lumbar lordosis in a straightened position and with the same the repositioning of COM to the rear in the direction of its physiological position[1,3]. Such a shifting of COM as well as the reduction of the field of foot support through the high raising of the heel of the foot may be equally a cause of the observed (in our own tests for footwear with a high heel) increased activeness of the spinal extensor both during the conducting of bending movement forward as in the position of maximum bend. Increased activeness of the spinal extensor during the movement of bending in footwear with a high heel can also be a cause of the impossibility of its relaxing at full bend (Flexion-Relaxation Position).

However, the reports occurring in the relevant literature on the subject of changes in the area of the pelvis and the section of the lumbar spine brought about by high heels are most equivocal in their findings. Opila-Correia[23] noted a flattening of the lumbar lordosis in young women when walking in footwear with a high heel (average age 26,3), while in older women (average age 43,7) there occurred a deepening of the lordosis. While Snow et al.[12] did not observe changes in the positioning of the pelvis and the lumbar spine while walking in high heels even though they noted at the same time a forward shifting of the COM.

There exists research that suggests that the long term use of footwear with a high heel results in compensatory changes in the activeness of muscles[1,10,11]. However, it results from these tests that the increased activeness of the paravertebral muscles brought about by the raising of the foot heel by that of the footwear may be compensated for through the shifting of the COM only to a certain height of heel. For the high raising of the heel results in an excessive burden of the spine at the height of the 4th lumbar vertebra[3,5]. In our own tests conducted during movements carried out in the sagittal plane there were not observed differences in the activeness of the spinal extensor between those measurements conducted without footwear and in footwear with a low heel, which could suggest that a heel of a height of 4 cm does not result in an overburdening of the lumbar section. However, observation of the work of these muscles during movements of rotation in the transverse plane shows their significant increase in activeness both in footwear with a low (4 cm) heel and in a high heel (10 cm), which also does not allow one to consider low heels as safe for the spine. Rotation in the lumbar section both in footwear with a low heel and a high heel creates a situation where balance is disturbed (unstable position) which may increase the activeness of the spinal extensor. The unstable position brought about by the heel can lead to disturbance in balance during the movements of pelvis rotation during walking and this may lead to chronic exhaustion of these muscles.

Certain researchers consider that a slight raising of the heel of the foot through an insert to the footwear or a low heel may have a beneficial influence on the reduction of complaints of pain experienced by a patient in the lower section of the spine[4,6]. One of the suggested mechanisms resulting in a reduction in symptoms amongst these patients as a consequence of applying a small raising of the foot's heel may be the normalisation within them of the lowered activeness of the spinal extensor during walking. Its earlier and greater activeness may help the stabilization of the pelvis and the lumbar section, reducing with the same problems resulting from the insufficient work of these muscles in individuals suffering pain[10,11,25]. Such a justification for the therapeutic effect of footwear with a heel is purposeful only given the assumption that the heel possesses a wide base or the raising of the heel of the foot occurs through a shoe insert providing the foot with total stable support. The significantly increased activeness in the spinal extensor during rotation movement observed in our research assessed on a low (4 cm) heel suggests that even a low heel but with a small support base has a detrimental overloading influence on the paravertebral muscles. Therefore, in recommending patients analgestic therapy incorporating the raising of the heel of the foot by a heel, essential is the selection of footwear which does not upset balance and which provides total support for the foot.

The utilisation of sEMG in the diagnosis of disturbances in activeness in the areas of spinal extensors has been described by numerous authors[26-28]. The results of their research are not however unequivocal. It is considered that the measurement of muscle activeness in a static position does not allow for an unequivocal differentiation of individuals with painful symptoms and those who are healthy, while the measurement of sEMG of the spinal extensor muscles in dynamic conditions during movement appears to be a method that is more reliable[29,30]. The results of our own research correspond with these findings, for in those tested in a free standing position both wearing low and high heels as well as without footwear the activeness of the spinal extensor was similar. What is more, differences in the activeness of the spinal extensor were not observed also during the movement of straightening the

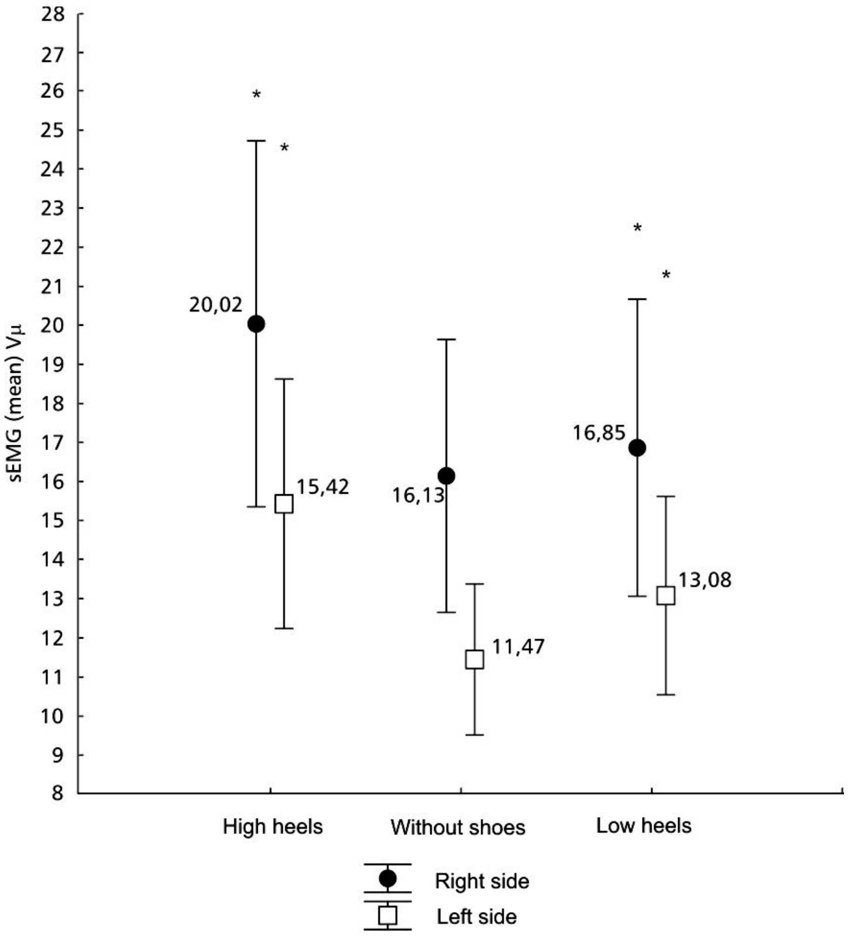

Figure 7

Mean value of erector spine activity (mean sEMG) during Rotation Left for 3 measurements respectively. Values are expressed as a mean ± SD; p<0,05

spine backwards in the sagittal plane. It may be therefore supposed that pain symptoms in the lumbar section of the spine in those tested did not occur, for the pain would more than likely have increased the activeness of muscles maesured while wearing high heels shoes.

The research into paravertebral muscle activeness in a standing position during the movement of bending and extending in the sagittal plane are not unequivocal in the aspect of the observed value of the sEMG signal[13,14,30]. During forward bending in healthy individuals there occurs, in the area of the paravertebral muscles, a phase of bioelectrical quiet/silence? This phenomenon is called bending–relaxation which occurs between 40º and 70º of the bending movement from a straightened standing position[14,16]. This is brought about by the end of the phase of proper bending in the lumbar section of the spine and the resulting relaxing of the paravertebral muscles. Further bending forward occurs thanks to the rotation of the pelvis and is controlled by the muscles acting on the pelvis (the gluteal and the bicipital of the thigh). During this bioelectric silence the paravertebral muscles act in a passive way on the lumbodorsal fascia, which in physiological conditions is sufficient to maintain the body in a bent position[31,32]. This mechanism is considered to be a protective factor for the ligaments of the spine protecting them from excessive stretching and damage[16].

This period of bioelectrical silence and the phenomenon of bending-relaxation connected with it does not occur in individual suffering from pain symptoms of the lumbar section of the spine[4,15]. The reasons for this state of affairs are ascribed to the heightened muscle tension caused by pain, by the conscious defensive reduction of the range of bending forward in the lumbar section as well as in the excessive reflect to extension in the area of the paravertebral muscles[18,33]. In our own tests the absence of relaxing of the spinal extensors in the position of full bending forward that was observed in footwear with high heels may suggest that the individuals tested were unable to relax these muscles in a controlled way during the phase of excentric work. The absence of differences in the values of the extension/flexion ratio between the measurements in low heels, high heels and without footwear allows one to suppose that the cause of the observed absence of the inactiveness of the extensor was not pain but an inability for the conscious control of muscle tension.

There exist reports that talk of how the irregularities in the working of the paravertebral muscles may be a likely cause of intensified feelings of pain in patients with chronic complaints in the section of the lumbar spine [34]. Disturbance in the balance in muscle tone may be the cause of the pain. It is suggested that incorrect muscle activeness causes the appearance of pathological tension in the area of the joints of the spine, ligaments, intervertebral discs and nerves, and that all these structures could be the source of pain stimuli. It has also been shown that in patients with chronic complaints of pain during the movement of bending forward there occurs an increase in tension in the area of the paravertebral muscles which causes a reduction in their oxygenation[35] limiting the inflow of natural analgetic substances resulting in an increased sense of pain [15]. The extending of this reduction in the inflow of endorphin to the muscles may lead to a reduction in the pain threshold, intensifying experienced of pain[36].

The standard method for the normalisation of the sEMG signal is the referencing of its value for a given muscle to the value obtained for this muscle during its maximum isometric contraction (MVC)[17]. Such a method for the normalisation of sEMG is appropriate for healthy individuals, however, in patients with painful symptoms of the lumbar section there is no possibility of a obtaining a maximum isometric contraction rendering this method useless[37,38]. An alternative for the normalisation of MVC is the extension/flexion ratio proposed by Watson et al.[18]. They showed that it is a reliable indicator in the identification of chronic pain symptoms in the lumbar spine and maybe a criterion for the differentiation of healthy individuals from those in pain.

Because in our own research the observed activeness of the spinal extensor in the position of maximum bend forward during a forward bend conducted in footwear with a high heel was statistically significantly higher than in footwear with a low heel and without shoes we should then expect that the extension/flexion ratio will be statistically significantly lower in the measurement for high heels in relation to the others. However, a lack of differences in the area of this ratio between the three measurements as well as the mean (but statistically significant) correlation between the activeness of the spinal extensor during bending movement forward and the ratio may suggest that the excessive activeness of the spinal extensor may be caused by other factors than pain, and result from the lack of an ability to relax this muscle during the carrying out of a bend forward.

There exists the need for further research with the aim of defining the height of raising the heel of the foot by the heel of a shoe and at which height the compensatory mechanisms of the organism become insufficient to counteract the excessive activeness of the paravertebral muscles, the changes in the range of reactive base forces, and the shifting of the COM. It seems desirable to extend the research into the phenomenon of changes in the activeness of the paravertebral muscles to incorporate a control group comprised of individuals with pain symptoms in the lumbar section of the spine, other age groups of patients as equally extending the number of the tested population.

Conclusions

1. In the tested group footwear with heels did not result in changes in the activeness of the spinal extensor at rest, however there was observed an increase in its activeness during movements made both in low heels as equally in high heels. This allows one to suppose that the long-term use of footwear with stiletto type heels may have a detrimental, overloading/overburdening influence on the paravertebral muscles.
2. The results of our own research allow us to suggest that the increased activeness of the spinal

extensor observed in footwear with heels may be caused by other factors than pain and may result from the lack of ability to relax this muscle, when carrying out movement, on the part of those tested. The simultaneously affirmed lack of differences in the value of the extension/flexion ratio in this group was confirmed by the observations of other authors and allows one to suppose that the extension/flexion ratio may constitute a criterion for the differentiation of healthy individuals from those in pain.

3. The increase in the activeness of the spinal extensor observed both during movements in the sagittal plane measured in high heels, as well as during movements in the transversal plane measured for low and high heels, allows one to suppose that the use of footwear of the stiletto type by individuals without pain symptoms in the lumbar section is dangerous for the spine and may lead to the chronic tiring of these muscles.

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