Industrial Health 2011, **49**, 403–409 **Original Article**

The Mechanical Effect of Anterior Pelvic Tilt Taping on Slump Sitting by Seated Workers

Jung-Hoon LEE[1] and Won-Gyu YOO[2]*

[1]Department of Physical Therapy, The Graduate School, Inje University, Republic of Korea
[2]Department of Physical Therapy, College of Biomedical Science and Engineering, Inje University, 607 Obang-dong, Gimhae, Gyeongsangnam-do 621-749, Republic of Korea

Received July 20, 2010 and accepted November 30, 2010
Published online in J-STAGE June 21, 2011

Abstract: The objectives of this study were to determine whether there is a change in the pelvic inclination after about 30 min of slump sitting by seated workers, and if so, to determine whether these changes can be prevented by the application of anterior pelvic tilt taping (APTT). The subjects who consented to participate in the experiment were randomly allocated to two groups: no-APTT group and APTT group. The no-APTT group performed slump sitting for 30 min, and the both pelvic inclinations were remeasured. In the APTT group, the both pelvic inclinations were measured immediately after the application of the APTT, and then again after 30 min of slump sitting. The both pelvic inclinations in the no-APTT group were significantly decreased ($p<0.05$) after they returned to the upright standing posture. The both pelvic inclinations in the APTT group were significantly increased immediately after the APTT ($p<0.05$), and this increase was maintained when returning to the upright standing posture after 30 min of slump sitting ($p>0.05$). We suggest that APTT can be applied as an auxiliary treatment method for preventing changes in pelvic inclination and musculoskeletal problems of low back area by awkward sitting posture in the seated worker.

Key words: Slump sitting, Anterior inclination of the pelvis, PALM, Kinesio Tape, Anterior pelvic tilt taping

Introduction

Many office workers spend long hours sitting at a desk[1)]. With the rapid progress of contemporary technology, the sitting position has become the most common posture in the workplace today[2)]. It has been found that three-quarters of all workers in industrialized countries are in sedentary jobs that require prolonged time in sitting postures[3)]. A recent study reported that workers in sedentary jobs spent an average of 10 h in a sitting posture during a 24-h period[4)]. Approximately one-third of office workers who use a visual display terminal (VDT) experience neck and back pain[5, 6)]. It is known that physical risk factors, such as prolonged sitting, may aggravate neck and back pain[7)]. The lifetime cumulative incidence of neck and shoulder symptoms was 57% among the office workers[8)]. The forward head posture (FHP), which is a combination of upper cervical extension, lower cervical flexion, and rounded shoulders, was generally adopted by office workers and related to musculoskeletal dysfunction[9)].

An epidemiologic investigation revealed that the incidence of low-back pain was higher in occupations that involve prolonged sitting[10)]. Previous studies have reported that prolonged sitting decreases the lumbar lordotic curve and increases intradiscal pressure, pressure on the ischium, and muscle activity[11, 12)]. It has been reported that prolonged flexion during sitting was the cause of redistribution of the nucleus within the annulus[13)]. Such factors together may eventually cause disc herniation, degeneration, or rupture, and potentially LBP[11, 12)]. Moreover, a prolonged static sitting posture may have a negative effect on the nutrition of the inter-

*To whom correspondence should be addressed.
E-mail: won7y@inje.ac.kr

Table 1. General characteristics of the subjects (N=56)

Variable	APTT group		no-APTT group	
	Male (n=15)	Female (n=13)	Male (n=15)	Female (n=13)
Age (yr)	23.80 ± 1.61*	21.46 ± 1.33	23.53 ± 1.86	25.31 ± 4.63
Height (cm)	172.09 ± 5.17	161.85 ± 4.34	172.67 ± 5.04	160.08 ± 4.72
Weight (kg)	68.13 ± 7.32	52.73 ± 6.56	67.60 ± 7.72	51.42 ± 4.38
Hour of VDT work (h/d)	7.03 ± 2.41	8.35 ± 1.46	7.73 ± 2.56	8.73 ± 2.23

*mean ± SD, APTT=Anterior Pelvic Tilt Taping.

vertebral disc[14].

Thus, it is important to teach seated workers to maintain the correct sitting posture when performing desk work[1]. The ideal seated posture is where the lumbar spine has some degree of extension (lordosis), whereas a poor posture is where the lumbar spine is kyphotic (slumped)[15]. However, for many people it is difficult to maintain the ideal sitting posture with the natural lordosis and increased anterior pelvic tilt, since fatigue of the lumbar extensor muscles increases when during prolonged sitting[16, 17]. Therefore, most seated workers adopt the relaxed or slumped sitting posture during long hours of desk work[1]. In slump sitting, the thoracolumbar spine is relaxed while looking straight ahead and the pelvis is in the posterior rotation position[18]. A posterior pelvic tilt decreases lordosis via flexion of the lumbar spine, causes posterior movement of the nucleus pulposus, and increases the diameter of the intervertebral foramina[16]. Slump sitting reduces the activation of the spinal stabilizing muscles[19] and is associated with increases in loading on the intervertebral disc[20] and connective tissue[21]. Clinically, it is known that passive postures such as slump sitting aggravate chronic low-back pain[22].

The elastic quality of Kinesio Tape (KT) may help to support or inhibit muscle function, support joint structure, reduce soft-tissue inflammation, reduce pain, and provide benefits to the sensorimotor and proprioceptive systems[23]. According to one study, KT might increase the provision of feedback to the muscles that sustain the stability of the thoracic spine and scapula as well as the preferred postural alignment[23]. However, it has yet to be determined whether application of KT can exert a mechanical effect on changes in pelvic inclination, or prevent pelvic deformation due to incorrect sitting. Hence, the objectives of this study were to determine whether there is a change in the anterior inclination of the pelvis after 30 min of sitting with a posterior pelvic tilt, also known as slump sitting, by seated workers, and if so, to determine whether the application of anterior pelvic tilt taping (APTT) with KT to both erector spinae (ES) and internal oblique (IO) muscles can prevent these changes.

Methods

Subjects

The 56 subjects who consented to participate in this experiment were randomly allocated to a no-APTT group (15 males and 13 females) or an APTT group (15 males and 13 females) using a computer-generated randomized table of numbers. Each of the subjects normally worked for more than 7 h in a seated position (Table 1). Subjects with limitation in the range of movement of the pelvis and spine, and orthopedic disabilities such as pain or neurologic deficits of the pelvis and spine during the previous year were excluded from the study. Prior to the start of the study, the subjects signed an informed-consent document that was approved by the Human Ethics Committee of the Faculty of Health Sciences at Inje University.

Instrumentation

A palpation meter (PALM, Performance Attainment Associates, St. Paul, MN, USA) was employed to measure the anterior inclination of the pelvis. This instrument comprises an inclinometer and two caliper arms. The PALM is a reliable and cost-effective measurement instrument for calculating the height discrepancy between landmarks[24, 25]. In a study involving measurement of differences in pelvic crest height difference, the PALM and radiographs yielded the same results[25]. Other studies in which the PALM was used to measure the ipsilateral anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS)[26–28]. Intra- and intertest reliabilities of 0.90 and 0.85, respectively, for this instrument.

Procedures

The subjects assumed an upright standing posture with the anterior aspect of the thighs against the stabilizing table[24]. The examiner palpated the prominences of the ipsilateral ASIS and PSIS, marking them with a black pen. The anterior inclination of the pelvis

was then measured with the caliper tips of the PALM at the marked ipsilateral ASIS and PSIS[29]. For the no-APTT Group, after 30 min of the slump sitting, the both anterior inclination of the pelvis was measured again in the upright standing posture. For the APTT Group, APTT was applied to the ES and IO muscles (acting on the anterior pelvic tilt) using KT after the initial measurement of pelvic anterior inclination. The tape was applied by a professional physical therapist who was experienced in this area, stretching the KT by 15–25%[30] while the subjects were in the upright standing position with the anterior aspect of the thighs against the stabilizing table. The APTT group was then asked to assume and maintain the slump sitting position for 30 min with ATTP, after which the anterior inclinations of both sides of the pelvis were remeasured in the upright standing posture (Fig. 1).

For the ES, the KT was applied from the iliac crest to the inferior borders of the angles of the lower six or seven ribs in the direction of the muscle fiber to impose a mechanical effect on the anterior pelvic tilt (Fig. 2). For the IO, the KT was applied obliquely, medially and upward to impose a mechanical effect, starting from the middle one-third of the intermediate line of the iliac crest in the origin to the inferior borders of ribs 10–12, the insertion, and the linea alba by means of an aponeurosis (Fig. 2). In addition, the margin of error was reduced as much as possible by having a single examiner measure the change in the anterior inclinations of both sides of the pelvis. Anterior and posterior pelvic tilts are defined as positive (+) and negative (–) tilt angles, respectively.

Data analysis

Statistical analysis was performed using the SPSS statistical package (version 14.0, SPSS, Chicago, IL, USA). The paired *t*-test was used for the no-APTT group to analyze statistically significant differences in anterior inclination of the pelvis between before and after slump sitting, whereas a repeated one-way ANOVA was used for the APTT group to analyze changes in the anterior inclination of the pelvis. Multiple comparisons were based on Bonferroni's correction. The level of statistical significance was set at $p<0.05$.

Results

The right (Rt) anterior inclination of the pelvis of the males in the no-APTT group was initially 8.03 ± 1.72° (mean ± SD); this changed to 5.19 ± 2.26° after 30 min of slump sitting; the left (Lt) anterior inclination of the pelvis changed from 8.30 ± 1.80° to 6.26 ± 2.44° (Table 2). The Rt anterior inclination of the pelvis

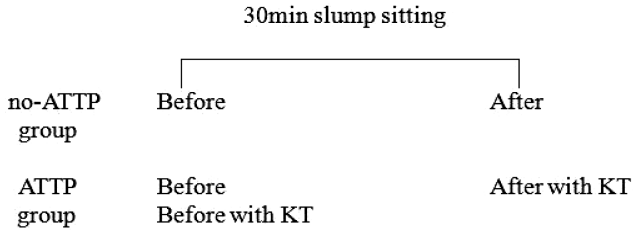

Fig. 1. Experimental conditions for measuring anterior inclination of the pelvis.

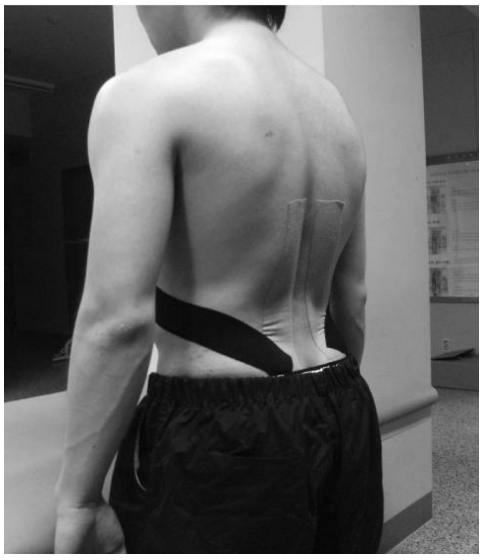

Fig. 2. APTT application for erector spinae (ES) muscle and internal oblique (IO) muscle.

of the females in the no-APTT group changed from 9.35 ± 2.27° to 6.55 ± 3.20° after 30 min of slump sitting, and the Lt anterior inclination of the pelvis changed from 9.35 ± 2.27° to 7.14 ± 2.96° (Table 2). For both the male and female subjects in the no-APTT group, both anterior inclinations of the pelvis decreased significantly when the subjects returned to the upright standing posture after 30 min of slump sitting ($p<0.05$).

The Rt anterior inclination of the pelvis of the males in the APTT group was 7.91 ± 2.56° initially, changing to 9.57 ± 2.62° immediately after the APTT application and to 9.81 ± 3.56° after 30 min of slump sitting. The Lt anterior inclination of the pelvis in these subjects was 7.18 ± 2.51° initially, 9.50 ± 1.92° immediately after the APTT application, and 10.61 ± 3.17° after 30 min of slump sitting (Table 3). The Rt anterior inclination of the pelvis of the females in the APTT group was 6.95 ± 2.95° initially, 9.19 ± 4.19° immediately after the APTT application, and 9.07 ± 3.19° after 30 min of slump sitting. These figures for Lt anterior inclination of the pelvis were 7.75 ± 2.83°, 9.72 ± 3.57°, and 9.35 ± 2.79°, respectively (Table 3). For both the male

Table 2. Comparison of the anterior pelvic tilt angle before and after slump sitting of no-APTT group (N=28)

Inclination	mean ± SD (Degrees)		*p*
	Before slump sitting	After slump sitting	
Rt. ASIS-PSIS Tilt Angle (M)	8.03 ± 1.72	5.19 ± 2.26	0.000
Lt. ASIS-PSIS Tilt Angle (M)	8.30 ± 1.80	6.26 ± 2.44	0.011
Rt. ASIS-PSIS Tilt Angle (F)	9.35 ± 2.27	6.55 ± 3.20	0.001
Lt. ASIS-PSIS Tilt Angle (F)	9.58 ± 2.34	7.14 ± 2.96	0.000

Rt: Right, Lt: Left, M: Male, F: Female.

Table 3. Comparison of the anterior pelvic tilt angle before and after APTT apply of APTT group (N=28)

Inclination	mean ± SD (Degrees)			*p*
	Before slump sitting	APTT apply	After slump sitting	
Rt. ASIS-PSIS Tilt Angle (M)	7.91 ± 2.56	9.57 ± 2.62	9.81 ± 3.56	0.011
Lt. ASIS-PSIS Tilt Angle (M)	7.18 ± 2.51	9.50 ± 1.92	10.61 ± 3.17	0.000
Rt. ASIS-PSIS Tilt Angle (F)	6.95 ± 2.95	9.19 ± 4.19	9.07 ± 3.19	0.006
Lt. ASIS-PSIS Tilt Angle (F)	7.75 ± 2.83	9.72 ± 3.57	9.35 ± 2.79	0.002

ASIS: Anterior Superior Iliac Spine, PSIS: Posterior Superior Iliac Spine.

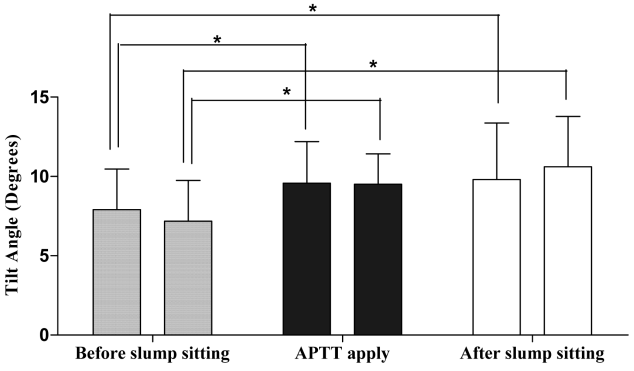

Fig. 3. Comparison of Rt. & Lt. ASIS-PSIS tilt angle of males in 3 conditions (*p<0.05).

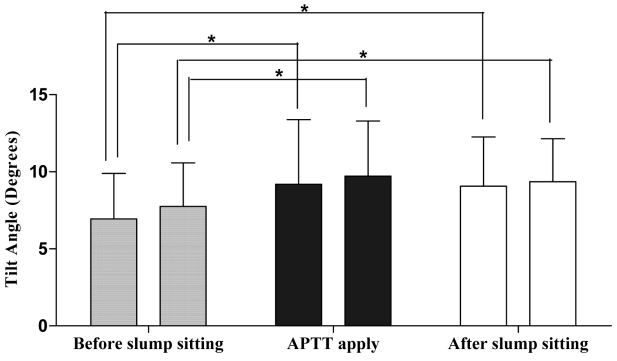

Fig. 4. Comparison of Rt. & Lt. ASIS-PSIS tilt angle of females in 3 conditions (*p<0.05).

and female subjects in the APTT group, the anterior inclination of both sides of the pelvis increased significantly immediately after the APTT application (p<0.05), and this increase was maintained when returning to the upright standing posture after 30 min of slump sitting (i.e., no significant decrease after slump sitting, p>0.05; Figs. 3 and 4).

Discussion

For all subjects in the no-APPT group, regardless of gender, anterior inclinations of the pelvis decreased significantly when they returned to an upright standing posture after 30 min of slump-sitting. All subjects in the APTT group, again regardless of gender, exhibited a significant increase in the anterior inclination of the pelvis immediately after the application of APTT, and this increase was maintained when returning to an upright standing posture after 30 min of slump sitting. The ES and IO muscles to which KT was applied in this study are the muscles that stabilize sacroiliac joint[16]. The ES may increase lumbar lordosis by causing anterior tilt of the pelvis, since it is attached to the sacrum and pelvis[16]. The upper anterior fibers of the IO, which are fixed at the thorax, may also contribute to anterior pelvic tilt[31].

It is known that the blood and lymph circulations may be enhanced at the sites where KT is applied, and thus the muscular and myofascial functions at those sites may be affected[32, 33]. The application of KT to the skin may stimulate cutaneous mechanoreceptors[34], strengthen the weakened muscles, and assist postural

alignment[35]. Thus, even in postures such as slump sitting, where external resistance causes posterior pelvic tilt, KT may stimulate cutaneous mechanoreceptors, causing anterior pelvic tilt after returning to the upright standing posture by enhancing the functions of the ES and IO muscles.

The results show that the posterior pelvic tilt persisted in the no-APTT group, even after returning to the upright standing posture following 30 min of slump sitting. Although the decreased anterior inclination of the pelvis did not cause abnormal pelvis deformation, which is a disease, continuous and habitual slump sitting may cause posterior pelvic tilt deformation. Some previous studies have reported that, although sitting itself is not closely related to lower back pain, a sitting position in association with other factors such as an awkward posture significantly increased the danger of lower back pain[36, 37]. In clinical settings, passive postures such as slump sitting have been identified as predictive of chronic lower back pain[22]. Compared with standing, the slumped posture resulted in not only the increase in spinal compression forces, but also deformation of the intervertebral discs[38]. Additionally, deformation of the intervertebral discs over time may impose more load on the facet joints[39], which may place more pressure on the nerves in the spinal column[40].

However, the results from the APTT group show that application of KT to the anterior pelvic tilt muscles exerts a mechanical benefit, preventing the reduction of the pelvic inclination that may occur when the pelvis rotates backward, as in slump sitting. It is thought that APTT can thus maintain the anterior inclination of the pelvis. However, it will be very difficult to establish a cause-and-effect relationship between position and pain[41]. The present study did not examine the mechanisms leading to pain in subjects with postural malalignment in any detail. The most important requirements regarding anterior pelvic tilt is to increase lumbar lordosis and optimize the entire spine alignment[16]. It has been reported that the maintenance of a normal lumbar lordotic curve is clinically associated with the prevention of spinal disorders[42].

Since the posture of the pelvis and lumbar spine greatly affect the posture of the other parts of the vertebral column, correction of the sitting posture may significantly influence the treatment and prevention of spinal problems[16]. Clinically, the general approach for the treatment of subjects with neck, shoulder, and back problems is posture correction[43]. Stability is usually required in the more proximal part of the body, such as the trunk, for effective motion and positioning of a distal structure[44], and interventional approaches for work-related neck and upper-limb disorders must focus on the trunk muscles prior to stretching and strengthening of the neck muscles[45]. A correct lower back posture by APTT application may have a beneficial effect on neck and shoulder posture, since this may not lead to musculoskeletal disorders to seated workers.

This study has some limitations. First, the change in the pelvis inclination by the APTT application was investigated in the study, but the change in the trunk by the APTT application was not evaluated. Second, how long the pelvic alignment was maintained after slump-sitting by the APTT application was not evaluated. Third, the appropriate APTT application duration was not investigated in a long-time study so that the possible side effects of prolonged anterior pelvic tilt might be excluded. Future research is also needed to address these issues.

Conclusions

We found that pelvic deformation to a posterior tilt may result when seated workers persistently assume the posterior pelvis tilt posture, such as in slump sitting. We suggest that APTT can be applied as an auxiliary treatment method for preventing pelvic deformation in the seated worker whose pelvis has been tilted posteriorly in this way, since APTT can maintain the anterior inclination of the pelvis.

Acknowledgements

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (No. 2010-0003874).

References

1) Watanabe S, Eguchi A, Kobara K, Ishida H (2007) Influence of trunk muscle co-contraction on spinal curvature during sitting for desk work. Electromyogr Clin Neurophysiol **47**, 273–8.
2) Li G, Haslegrave CM (1999) Seated postures for manual, visual and combined tasks. Ergonomics **42**, 1060–86.
3) Reinecke SM, Hazard RG, Coleman K, Pope MH (2002) A continuous passive lumbar motion device to relieve back pain in prolonged sitting. In: Kumar S (Ed.), Advances in industrial ergonomics and safety IV, 971–6, Taylor and Francis, London.
4) McCrady SK, Levine JA (2009) Sedentariness at work: how much do we really sit? Obesity **17**, 2103–5.
5) Aaras A, Fostervold KI, Ro O, Thoresen M, Larsen S (1997) Postural load during VDU work: a comparison between various work postures. Ergonomics **40**,

1255–68.
6) Braun BL (1991) Postural differences between asymptomatic men and women and craniofacial pain patients. Arch Phys Med Rehabil **72**, 653–6.
7) Ariens GAM, Bongers PM, Hoogendoorn WE, Houtman ILD, van der Wal G, van Mechelen W (2001) High quantitative job demands and low coworker support as risk factors for neck pain. Spine **17**, 1896–903.
8) Tola S, Riihimäki H, Videman T, Viikari-Juntura E, Hänninen K (1988) Neck and shoulder symptoms among men in machine operating, dynamic physical work and sedentary work. Scand J Work Environ Health **14**, 299–305.
9) Szeto GP, Straker L, Raine S (2002) A field comparison of neck and shoulder postures in symptomatic and asympomatic office worker. Appl Ergon **33**, 75–84.
10) Williams MM, Hawley JA, McKenzie RA, van Wijmen PM (1991) A comparison of the effects of two sitting postures on back and referred pain. Spine **16**, 1185–91.
11) Claus A, Hides J, Moseley GL, Hodges P (2008) Sitting versus standing: does the intradiscal pressure cause disc degeneration or low back pain? J Electromyogr Kinesiol **18**, 550–8.
12) Makhsous M, Lin F, Bankard J, Hendrix RW, Hepler M, Press J (2009) Biomechanical effects of sitting with adjustable ischial and lumbar support on occupational low back pain: evaluation of sitting load and back muscle activity. BMC Musculoskelet Disord **10**, 17.
13) McKenzie RA (1979) Prophylaxis in recurrent low back pain. N Z Med J **89**, 22–3.
14) Marras WS, Lavender SA, Leurgans SE, Fathallah FA, Ferguson SA, Allread WG, Rajulu SL (1995) Biomechanical risk factors for occupationally related low back disorders. Ergonomics **38**, 377–410.
15) Reynolds HM, Brodeur R, Eppler M, Neal D, Rayes K, Kerr R, Stockman G (1995) The Initial Position and Postural Attitudes of Driver Occupants. Experimental Protocol. ERL-TR-95-001, Ergonomics Research Laboratory, Michigan State University.
16) Neumann DA (2002) Kinegiology of the musculoskeletal system: foundations for physical rehabilitation, 1st Ed., Mosby, St Louis.
17) Carter JB, Banister EW (1994) Musculoskeletal problems in VDT work: a review. Ergonomics **37**, 1623–48.
18) Caneiro JP, O'Sullivan P, Burnett A, Barach A, O'Neil D, Tveit O, Olafsdottir K (2010) The influence of different sitting postures on head/neck posture and muscle activity. Man Ther **15**, 54–60.
19) O'Sullivan PB, Grahamslaw KM, Kendell M, Lapenskie SC, Möller NE, Richards KV (2002) The effect of different standing and sitting postures on trunk muscle activity in a pain-free population. Spine **27**, 1238–44.
20) Macintosh JE, Bogduk N, Pearcy MJ (1993) The effects of flexion on the geometry and actions of the lumbar erector spinae. Spine **18**, 884–93.
21) Adams MA, Hutton WC (1983) The effect of posture on the fluid content of lumbar intervertebral discs. Spine **8**, 665–71.
22) O'Sullivan PB (2000) Lumbar segmental 'instability': clinical presentation and specific stabilizing exercise management. Man Ther **5**, 2–12.
23) Jaraczewska E, Long C (2006) Kinesio® taping in stroke: improving functional use of the upper extremity in hemiplegia. Top Stroke Rehabil **13**, 31–42.
24) Petrone MR, Guinn J, Reddin A, Sutlive TG, Flynn TW, Garber MP (2003) The accuracy of the palpation meter (PALM) for measuring pelvic crest height difference and leg length discrepancy. J Orthop Sports Phys Ther **33**, 319–25.
25) da Costa BR, Armijo-Olivo S, Gadotti I, Warren S, Reid DC, Magee DJ (2010) Reliability of scapular positioning measurement procedure using the palpation meter (PALM). Physiotherapy **96**, 59–67.
26) Krawiec CJ, Denegar CR, Hertel J, Salvaterra GF, Buckley WE (2003) Static innominate asymmetry and leg length discrepancy in asymptomatic collegiate athletes. Man Ther **8**, 207–13.
27) Preece SJ, Willan P, Nester CJ, Graham-Smith P, Herrington L, Bowker P (2008) Variation in pelvic morphology may prevent the identification of anterior pelvic tilt. J Man Manip Ther **16**, 113–7.
28) Gnat R, Saulicz E, Biały M, Kłaptocz P (2009) Does pelvic asymmetry always mean pathology? Analysis of mechanical factors leading to the asymmetry. J Human Kinetics **21**, 23–35.
29) Krawiec CJ, Denegar CR, Hertel J, Salvaterra GF, Buckley WE (2003) Static innominate asymmetry and leg length discrepancy in asymptomatic collegiate athletes. Man Ther **8**, 207–13.
30) Kase K, Wallis J (2002) The latest Kinesio taping method. Ski-Journal, Tokyo.
31) Kendall FP, McCreary EK, Provance PG, Rodgers MM, Romani WA (2005) Muscles: testing and function, with posture and pain, 5th Ed., Lippincott Williams & Wilkins, Baltimore.
32) Kase K, Wallis J, Kase T (2003) Clinical therapeutic applications of the Kinesio® taping method. NM, Kinesio® Taping Association, Albuquerque.
33) Yoshida A, Kahanov L (2007) The effect of kinesio taping on lower trunk range of motions. Res Sports Med **15**, 103–12.
34) Murray H, Husk L (2001) Effect of Kinesio™ taping on proprioception in the ankle. J Orthop Sports Phys Ther **31**, A–37.
35) Kaya E, Zinnuroglu M, Tugcu I (2011) Kinesio taping compared to physical therapy modalities for the treatment of shoulder impingement syndrome. Clin Rheumatol **30**, 201–7.
36) Hartvigsen J, Leboeuf-Yde C, Lings S, Corder EH (2000) Is sitting-while-at-work associated with low back pain? A systematic, critical literature review.

Scand J Public Health **28**, 230–9.
37) Lis AM, Black KM, Korn H, Nordin N (2007) Association between sitting and occupational LBP. Eur Spine J **16**, 283–98.
38) Todd AI, Bennett AI, Christie CJ (2007) Physical implications of prolonged sitting in a confined posture —a literature review. Ergonomics SA **19**, 7–21.
39) Cheung JT-M, Zhang M, Chow DH-K (2003) Biomechanical responses of the intervertebral joints to static and vibrational loading: a finite element study. Clin Biomech **18**, 790–9.
40) Corlett EN (2006) Background to sitting at work: research requirements for the design of work seats. Ergonomics **49**, 1538–46.
41) Callaghan JP, Dunk NM (2002) Examination of the flexion relaxation phenomenon in the erector spinae muscles during short duration slumped sitting. Clin Biomech **17**, 353–60.
42) Tsuji T, Matsuyama Y, Sato K, Hasegawa Y, Yimin Y, Iwata H (2001) Epidemiology of low back pain in the elderly: correlation with lumbar lordosis. J Orthop Sci **6**, 307–11.
43) Straker L, Mekhora K (2000) An evaluation of visual display unit placement by electromyography, posture, discomfort and preference. Int J Ind Ergon **26**, 389–98.
44) Kisner C, Colby LA (2002) Therapeutic exercise: foundations and techniques, 4th Ed., 13–24, FA Davis Company, Philadelphia.
45) Yoo WG, Yi CH, Kim MH (2006) Effects of a proximity-sensing feedback chair on head, shoulder, and trunk postures when working at a visual display terminal. J Occup Rehabil **16**, 631–7.