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ANALYSIS OF A DIFFERENCE IN THE BIOMECHANICAL CHARACTERISTICS ACCORDING TO THE HABITUATION BY HEIGHTS OF SHOES: HIGH-HEEL AND LOW-HEEL SHOES

Yu-Jin Cha
Department of Occupational Therapy, Semyung University, Jecheon, Republic of Korea
occujin@naver.com

Abstract

This study was performed to comprehensively investigate whether there is a difference in the biomechanical characteristics according to the habituation by heights of shoes of those who habituate to high heeled shoes and low heeled shoes. The women with low heeled habituation show significantly higher values of peak pressures in the lateral forefoot and midfoot areas, and wider contact areas in toes and midfoot than the women with high heeled habituation for the contact area. From the EMG comparison, the women with high heeled habituation show significantly higher maximum peak EMG in GM, and from the percentage of maximum voluntary isometric contraction (%MVIC), the women with high heeled habituation show significantly higher values of the plantarflexion in GM the low heeled shoe user. For the static balance, the women with high heeled habituation show significantly greater values with eyes open. The study was able to verify that there is a significant difference in biomechanical fitness such as foot pressure, %MVIC, etc. Based on the result, this study can be utilized as base data to develop a customized insole that disperses pressure and softens shock absorption of the high heeled shoes.
Keywords
Biomechanics, EMG, Foot Pressure, Habituation, High Heels, Muscle Activation, Static Balance

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1. Introduction

The high heeled shoes have evolved into various forms as recognized by a part of the fashion, and many types of research on the impact on ambulation have been conducted (Kim & Lim, 2016). Recently as major news media in U.S. intensively reported diseases and/or problems caused by shoes, the media severely warned with expressions such as ‘High heels killing you?’, ‘The curse of high heels’, etc. (Associated Newspapers Ltd, 2017; Korea Consumer Agency, 1998).

In U.S., around 40% of adults have foot-related diseases, and it has been reported that it requires USD 1.5 trillion of direct expenses for an operation and post-operative care to treat hallux valgus, bunion, hammer toe, corm, low back pain, etc., and USD 15 trillion of indirect expenses are spent among the majority of adults with the foot-related diseases. However, despite invisible pains due to the high cost, inconvenience, and malformation, women prefer high heeled shoes and spend most of the time with wearing high heeled shoes (Coughlin & Thompson, 1995). In Korea, according to statistical data from Health Insurance Review & Assessment Service (HIRA), the plantar fasciitis is a disease which frequently occurs in women due to the shoes which have difficulties to absorb an impact such as high heeled shoes, and the number of patients who were treated for the plantar fasciitis was increased by 1.26 times from 180,062 in 2014 to 227,418 in 2016. The expenses were also increased by 1.33 times from KRW 11.67 billion to KRW 15.51 billion (Korea National Statistical Office, 2016).

The high heeled shoes increase the plantar flexion of feet and instability of ankle joints is increased as supporting areas are reduced. Also, as momentum of outer sides of feet is increased, ankle sprains and falls might be caused, and in case of wearing the high heeled shoes for long time, it may reduce efficiency by increasing energy consumption during walking. In addition, by accelerating muscular fatigue, it stresses out feet (Song & Park, 2001). As the center of gravity of the body changes, it not only changes alignment of the body but also gives a harmful influence to walking and functions of low extremities (Moon & Kim, 2011).
There is a significant difference between the women with high heeled habituation and women with low heeled habituation, and a prolonged use of the high heeled shoes bring differences in a malfunction of a sensory function change to a center line of the balance of ankles and knee joints, etc. (Lee et al., 2010), while the women with low heeled habituation show differences such as reduced muscle activation, activation of the biceps femoris, etc. (Park et al., 1999), but there are insufficient aspects as only a single aspect which is a kinetic aspect was reviewed.

There are many results of researches on the high heeled shoes for this study, but not much researches on the impact derived from habituation of the high heeled hoses. Therefore, this study was performed to comprehensively investigate whether there is a difference in the biomechanical characteristics according to the habituation by heights of shoes of those who habituate to high heeled shoes (“women with high heeled habituation”, more than 6cm) and low heeled shoes (women with low heeled habituation” lower than 3cm). This study intends to provide basic data for developing customized insoles that have aesthetic factors, convenience, and biocompatibility as well as the capability to disperse pressure and absorb and release shocks caused by various types of high-heeled shoes, differentiated according to habituation by heel height.

2. Methods

The comparison analysis was comprehensively performed to check if there is a difference in a level of the biomechanical characteristics through surface EMG, foot pressure analysis, static dynamic balance measurement in order to compare functional variables related between women with high heeled habituation and women with low heeled habituation.

2.1 Research Subject and Period

The research subjects consist of total 37 healthy women in 20s, 19 women with high heeled habituation who habituate to living with wearing high heeled shoes, higher than 6 cm and 18 women with low heeled habituation, lower than 3 cm for more than recent 1 year, 3 days a week and 4 hours a day (Kim et al., 2015; Snow & Williams, 1994).

2.2 Research Tools

Followings are the analytical equipment and variables used for this study (Table 1).
Table 1: Equipments

| Equipment                                      | Model       | Company                  | Variables                               |
|------------------------------------------------|-------------|--------------------------|-----------------------------------------|
| Plug-in shoe type foot pressure measuring equipment | Pedar® system | Novel GMBH, Germany       | peak pressure (PP) (kPa) contact area (CA) (cm²) |
| Surface EMG                                    | Noraxon EMG | Noraxon, USA              | RMS EMG (uV) %MVIC                       |
| Balance measuring equipment                    | Gaitview    | allFOOTs, Korea          | Displacement of a center of pressure (COP) |

* Measure a dominant leg

2.3 Research Procedure

The subjects of this study is categorized by the women with high heeled habituation (Group A) and women with low heeled habituation (Group B). In order to examine the muscle activation, perform a measurement for 20 seconds standing on a measuring plate, Gaitview system, with both feet by attaching EMG electrodes to 7 points and wearing experimental shoes, 7cm, with a remote sensor attached to Pedar® system in an inner sole which is a foot pressure measuring equipment. Measure 3 times, 20 seconds for each, and take a 10 seconds break between the tests, and then calculate average values (Lee et al., 2010). All measurements were performed with a dominant leg, and a leg used to kick a ball was considered as a dominant leg.
2.4 Analytical Method

Data treatment of this study was analyzed by SPSS (version 22.0-Chicago, IL, USA). General characteristics of the subjects are i) calculating average and standard deviation, ii) performing a homogeneity analysis and iii) t-test with an independent sample was performed to analyze differences in foot pressure, surface EMG and balance between the women with high heeled habituation and women with low heeled habituation. A statistical significant level is $\alpha=.05$.

3. Results

The age is $20.11 \pm 1.59$ years, weight is $53.29 \pm 4.07$ kg, height is $169.56 \pm 3.71$ cm and shoe size is $240 \pm 3.22$ mm of the group A, and for the group B, the age is $19.66 \pm 1.14$ years, weight is $54.11 \pm 5.09$ kg, height is $165.78 \pm 3.87$ cm and shoe size is $246.23 \pm 2.56$ mm. Since there was no significant difference in the age, weight, height and shoe size as a result of the homogeneity analysis of the two groups, the two groups can be a homogeneous group.

Table 2: Participant Demographics (N= 37)

| Variables     | Group A<sup>a</sup> (N=19) | Group B<sup>b</sup> (N=18) | t   | p   |
|---------------|-----------------------------|-----------------------------|-----|-----|
| Age (years)   | 20.11 ± 1.59                | 19.66 ± 1.14                | 0.958 | 0.090 |
| Weight (kg)   | 53.29 ± 4.07                | 54.11 ± 5.09                | -    | 0.544 |
| Height (cm)   | 167.45 ± 3.13               | 165.78 ± 3.87               | 1.450 | 0.237 |
| Shoes size (mm)| 240 ± 3.22                  | 246.23 ± 2.56               | 0.414 | 0.376 |

Values are means ± SE
<sup>a</sup>Over 12 months, 4 times a week, and over 6cm heeled shoes group
<sup>b</sup>Over 12 months, 4 times a week, and below 3cm heeled shoes group

From the foot pressure analysis between group A and B, the group B show significantly higher values of peak pressures (PP) in lateral forefoot and midfoot areas than the group A. For the contact area, the women with low heeled habituation show significantly higher values in toes and midfoot than the group A ($p<.05$) ($p<.001$) (Figure 2) (Table 3).
**Table 3:** Average Pressure by Each Area of the Women with High Heeled Habituation and Women with Low Heeled Habituation

| Variables          | Group A<sup>a</sup> | Group B<sup>b</sup> | t    | p    |
|--------------------|---------------------|---------------------|------|------|
| Hallus PP (kPa)    | 56.04 ±13.13        | 54.04±19.58         | .368 | .715 |
| Hallus CA (cm<sup>2</sup>) | 8.39 ±1.52           | 8.00±1.77           | .653 | .518 |
| Toes PP (kPa)      | 24.78 ±7.93         | 26.94±7.10          | -.869| .391 |
| Toes CA (cm<sup>2</sup>) | 5.71±1.93          | 7.16±2.09           | -2.210| .034<sup>*</sup> |
| Medial forefoot PP (kPa) | 75.77 ±20.30        | 81.75±15.96         | -.993| .328 |
| Medial forefoot CA (cm<sup>2</sup>) | 17.79±1.73           | 17.82±2.27          | .090 | .929 |
| Lateral forefoot PP (kPa) | 62.35 ±13.12        | 77.39±15.14         | 15.003| .000<sup>**</sup> |
| Lateral forefoot CA (cm<sup>2</sup>) | 16.01±1.90           | 16.69±1.92          | -1.062| .296 |
| Midfoot PP (kPa)   | 23.03 ±9.36         | 37.22±14.00         | -3.606| .001<sup>**</sup> |
| Midfoot CA (cm<sup>2</sup>) | 5.60±3.57            | 8.70±3.62           | -2.669| .012<sup>*</sup> |
| Heel PP (kPa)      | 93.24 ±18.11        | 97.69±17.94         | -.750| .458 |
| Heel CA (cm<sup>2</sup>) | 27.43±1.52           | 28.26±2.58          | -1.086| .285 |
| Lateral heel PP (kPa) | 90.16 ±19.15        | 95.34±18.31         | -.840| .406 |
| Lateral heel CA (cm<sup>2</sup>) | 19.17±4.95           | 18.37±1.00          | .723 | .478 |

<sup>*</sup>p<.05,  **<sup>p</sup><.001

Values are means ± SE

CA, contact area; PP, peak pressure
Contact Area (CA)

**Figure 2:** Peak Pressure (PP) and Contact Area (CA). Error Bars Represent One Standard Deviation

In the maximum peak EMG comparison, it shows a significant difference in Medical Gastrocnemius (GM), and the group A show higher values than the group B (p<.05) (p<.001) (Table 4).

**Table 4:** Muscle Activation Comparison between the Women with High Heeled Habituation and the Women with Low Heeled Habituation

| Variables        | Group A^a | Group B^b | t   | p   |
|------------------|-----------|-----------|-----|-----|
| TA               | RMS EMG (μV) | 6.07±3.22 | 7.04±3.23 | -.906 | .371 |
|                  | Maximum Peak EMG (μV) | 329.84±146.42 | 339.76±169.95 | -.188 | .852 |
| RF               | RMS EMG (μV) | 8.10±7.02 | 6.87±5.65 | .573 | .571 |
|                  | Maximum Peak EMG (μV) | 260.80±182.39 | 274.99±189.85 | -.229 | .821 |
| GM               | RMS EMG (μV) | 9.96±3.21 | 7.19±4.99 | 1.998 | .054 |
|                  | Maximum Peak EMG (μV) | 487.79±194.26 | 324.94±130.18 | 2.918 | .006^{*} |
| GL               | RMS EMG (μV) | 5.66±3.97 | 6.38±2.82 | -.620 | .540 |
|                  | Maximum Peak EMG (μV) | 286.89±207.10 | 327.06±141.82 | -.671 | .507 |
| BF               | RMS EMG (μV) | 2.69±1.74 | 3.70±2.24 | -1.519 | .138 |
|                  | Maximum Peak EMG (μV) | 148.56±88.33 | 202.81±100.61 | -1.723 | .094 |
| ES               | RMS EMG (μV) | 2.98±0.73 | 3.54±2.00 | -1.145 | .260 |
|                  | Maximum Peak EMG (μV) | 156.26±38.95 | 193.01±92.77 | -1.580 | .123 |
From the percentage of maximum voluntary isometric contraction (%MVIC), the group A show significantly higher values of the plantarflexion in GM than the group B (p<.05) (Table 5).

**Table 5:** Muscle Activation Comparison (%MVIC) between the Women with High Heeled Habituation and the Women with Low Heeled Habituation

| Variables | Group A<sup>a</sup> | Group B<sup>b</sup> | t     | p      |
|-----------|---------------------|---------------------|-------|--------|
| TA (%MVIC) | Plantarflexion      | 2.98±1.27           | 4.39±2.93 | -1.837 | .080  |
|           | Dorsiflexion        | 0.56±0.48           | 0.96±5.20 | -1.590 | .121  |
| GM (%MVIC) | Plantarflexion      | 12.57±10.49         | 6.92±4.80 | 2.080  | .047<sup>*</sup> |
|           | Dorsiflexion        | 2.90±2.11           | 4.06±0.99 | -1.323 | .195  |
| GL (%MVIC) | Plantarflexion      | 2.86±1.18           | 4.27±3.09 | -1.177 | .255  |
|           | Dorsiflexion        | 6.52±4.63           | 7.16±4.90 | -.402  | .690  |

*p<.05, **p<.001
Values are means ± SE

The static balance shows a significant difference in case of eyes open (EO). As the shorter COP implies a better balance ability, the group A show significantly higher COP than the group B.

**Table 6:** Balance Ability Comparison between the Women with High Heeled Habituation and the Women with Low Heeled Habituation

| Variables | Group A<sup>a</sup> | Group B<sup>b</sup> | t      | p      |
|-----------|---------------------|---------------------|--------|--------|
| Static balance (COP) | EO     | 110.51±23.78       | 177.48±136.96 | -1.450 | 0.016<sup>*</sup> |
|           | EC      | 141.74±44.07       | 120.23±41.69 | -0.759 | 0.152  |

*p<.05
Values are means ± SE
EO, eye opening; EC, eye close; COP, center of pressure

**4. Discussion**

In modern society, the high heeled shoes that women prefer has emphasized a feature pursuing an individuality and aesthetic beauty than a functional feature of shoes to protect...
feet and support walking. Although it has been already reported that the high heeled shoes cause various functional problems and damages to the musculoskeletal system, this study comprehensively compares and analyzes differences in a level of the biomechanical characteristics between the two groups of the women with high heeled habituation (higher than 6cm) and women with low heeled habituation (lower than 3cm) in order to examine biomechanical changes caused by wearing high heeled shoes for long time.

The results of this study say that form the PP comparison between the women with high heeled habituation and women with low heeled habituation, the low heeled shoe user show significantly higher values of PPs in lateral forefoot and midfoot areas, and wider contact areas in toes and midfoot than the women with high heeled habituation for the contact area. From the maximum peak EMG the women with high heeled habituation show significantly higher values in GM than the women with low heeled habituation. In the comparison of %MVIC between the two groups, the women with high heeled habituation show significantly higher values of the plantar flexion in GM the low heeled shoe user. For the static balance, the women with high heeled habituation show significantly greater values than the women with low heeled habituation with eyes open. In other words, the high heeled users show higher values in the maximum peak EMG, plantar flexion of GM and have a better static balance ability. The women with low heeled habituation show higher values in the Lateral forefoot and midfoot areas from the PP comparison, and wider contact areas in the toes and midfoot areas.

It has been reported that increase of the PP promotes degeneration of ankle joints, and it is a direct cause which induces arthritis and pains. Small contact areas increase instability and momentum, and cause ankle sprains and falls (Putti et al., 2007; Jung et al., 2012). Especially, it is said that compensatory actions occur in knee joints and/or hip joints in order to compensate for reduced stability in ankles while walking with waring high heeled shoes (Lee et al., 2010). Therefore, if the women with low heeled habituation wear high heeled shoes that they don’t usually habituate to wear, they are much more exposed to such negative problems, and in particular, it was shown that a phenomenon where a weight is born on a front side of a foot including toes noticeably comes up.

The existing analysis research results of the muscle activation show the same results as the research (Gefen et al., 2000) by indicating imbalance of medial gastrocnemius (GM) activities in the EMG measurement of the women with high heeled habituation, and activities of ankles, soleus muscle and rectus femoris (RF) are increased according to the height of heels. This is because a side incline tendency focused on a pressure of the women with high
heeled habituation causes imbalanced activities by increasing fatigues in GL and GM (Moon & Kim, 2011).

Also, it accords with the research of Lee et al. which says that prolonged wearing time of high heeled shoes increases the muscle activation of GM and GL which are flexor muscles of the sole. As a result, it causes imbalance of muscles, disk, degenerative arthritis, swollen and benumbed feet, body shape change, etc. (Lee et al., 2010). It also accords with the research which says that the study conducted with men who habituate to low heeled shoes shows there is no change to the percentage of maximum muscle activation of anterior tibialis (AT) as a result of a measurement measuring electromyogram sings of AT and gastrocnemius while walking with wearing high heeled shoes, but the percentage of maximum muscle activation of gastrocnemius is reduced (Shin et al., 2012).

The women with high heeled habituation show a higher static balance ability, and it is accords with results of the research conducted by Lee and others which says that women who habituate to waring high heeled shoes feel less instability while wearing high heeled shoes and the research of Snow and Williams which shows that as the center of gravity moves forward, it gives a positive influence to the balance adjustment and causes the kinetic adaptation phenomenon (Lee et al., 1990; Snow & Williams, 1994).

This study can verify significant differences in the biomechanical adaptation such as the center of gravity, muscle activation, balance, etc. between the women with high heeled habituation and women with low heeled habituation. As there is a challenge to generalize results of this study because the subjects of the study consist of women in early 20s, it is necessary to conduct a further study expanded to various age groups, type of heels and group of men who habituate to wearing high heeled shoes. As there is a challenge to generalize results of this study because the subjects of the study consist of women in early 20s, it is necessary to conduct a further study expanded to various age groups, type of heels and group of men who habituate to wearing high heeled shoes.

5. Conclusions

In order to examine biomechanical changes caused by wearing high heeled shoes for long time, this study comprehensively performed the comparison analysis to check if there is a difference in a level of the biomechanical characteristics through surface EMG, foot pressure analysis, static dynamic balance measurement to compare functional variables between the women with high heeled habituation (higher than 6cm) and women with low heeled habituation (lower than 3cm). The results of this study say that form the PP comparison between the women with high heeled habituation and women with low heeled
habituation, the low heeled shoe user show significantly higher values of PPs in lateral forefoot and midfoot areas, and wider contact areas in toes and midfoot than the women with high heeled habituation for the contact area. From the maximum peak EMG the women with high heeled habituation show significantly higher values in GM than the women with low heeled habituation. In the comparison of MVIC between the two groups, the women with high heeled habituation show significantly higher values of the plantarflexion in GM the low heeled shoe user. For the static balance, the women with high heeled habituation show significantly greater values than the women with low heeled habituation with eyes open. In conclusion, this study can verify significant differences in the biomechanical adaptation such as the center of gravity, muscle activation, balance, etc. between the women with high heeled habituation and women with low heeled habituation. It is necessary to conduct a further study expanded to various age groups, type of heels and group of men who habituate to wearing high heeled shoes.

6. Abbreviations

   HH, high heels; %MVIC, percentage of maximum voluntary isometric contraction; EMG, electromyography; COP, center of pressure; EO, eye opening; EC, eye close; COP, center of pressure; TA, tibialis anterior; RF, Rectus femoris; GM, medial gastrocnemius; GL, lateral gastrocnemius; BF, Biceps Femoris; ES, Thoracic Erector Spinae; CA, contact area; PP, peak pressure; SE, standard error

7. Conflicting Interests

   The author declares that he has no competing interests.

8. Consent for Publication

   No applicable.

9. Ethics Approval and Consent to Participate

   I obtained an exemption from the Institutional Review Board at the Semyung University (SMU-2018-09-004).

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11. Availability of Data and Materials

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

12. Author’s Contributions

YJC has solely carried out the data analysis, wrote and approved the manuscript.

References

Associated Newspapers Ltd. (2017). 10 reasons why your high heels are killing you. http://www.dailymail.co.uk/health/article-4167014/10-reasons-high-heels-killing-you.html. Accessed August 1 2018.

Coughlin, M. J., & Thompson, F. M. (1995). The high price of high-fashion footwear. Instructional Course Lectures, 44, 371-378.

Gefen, A., Megido-Ravid, M., Itzchak, Y., & Arcan, M. (2000). Biomechanical analysis of the three-dimensional foot structure during gait: a basic tool for clinical applications. Journal of Biomechanical Engineering, 122, 630-639. https://doi.org/10.1115/1.1318904

Jung, J. Y., Park, I. S., Won, Y. G., Kwon, D. K., & Kim, J. J. (2012). Effects of Forefoot Rocker Bottom shoes with Metatarsal Bar on gait during the stance phase of human walking. 2012 Conference of Ergonomics Society of Korea, 86-92.

Kim, E. J., Jeon, S. B., & Jeong, K. Y. (2015). Influences of short-term high-heeled walking on the activities of ankle-stabilizing muscles in healthy young females. Journal of Korean Academy of Orthopedic Manual Therapy, 21, 39-46.

Kim, M. Y., & Lim, B. O. (2016). Effect of 12 Weeks Exercise Program on Lower Extremity Muscle Activities during Freezing of Gait in Patients with Parkinson's Disease. Journal of Korean Association of Physical Education and Sport for Girls and Women, 30, 415-428. https://doi.org/10.16915/jkapesgw.2016.12.30.4.415

Korea National Statistical Office. (2016). Disease sub-category statistics. Plantaritis. Retrieved from http://opendata.hira.or.kr/

Lee, H. J., Lee, S. J., & Tae, K. S. (2010). Comparison of Balance Ability on the Heel Height and the Habituation to the High Heel. Journal of Biomedical Engineering Research, 31, 106-113.

Lee, K. H., Shieh, J. C., Matteliano, A., & Smiehorowski, T. (1990). Electromyographic changes of leg muscles with heel lifts in women: therapeutic implications. Archives of Physical Medicine and Rehabilitation, 71, 31-33.
Moon, G. S., & Kim, T. H. (2011). The Effect of Total Contact Inserts on the Gait Parameters During High-Heeled Shoes Walking. *Korean Research Society of Physical Therapy*, 18, 1-8.

Park, E. Y., Kim, W. H., Kim, G. O., & H., C. S. (1999). Effects of high-heel shoes on EMG activities of rectus femoris and biceps femoris. *Korean Research Society of Physical Therapy*, 6, 32-42.

Putti, A. B., Arnold, G. P., Cochrane, L., & Abboud, R. J. (2007). The Pedar® in-shoe system: repeatability and normal pressure values. *Gait & Posture*, 25, 401-405. [https://doi.org/10.1016/j.gaitpost.2006.05.010](https://doi.org/10.1016/j.gaitpost.2006.05.010)

Korea Consumer Agency. (1998). Prevent foot disease caused by shoes. [https://www.ciss.go.kr/www/selectBbsNttView.do?key=78&bbsNo=86&nttNo=4079&searchCtgrv=&searchCnd=all&searchKrwd=&pageIndex=152&pageUnit=10&intgrDeptCode=](https://www.ciss.go.kr/www/selectBbsNttView.do?key=78&bbsNo=86&nttNo=4079&searchCtgrv=&searchCnd=all&searchKrwd=&pageIndex=152&pageUnit=10&intgrDeptCode=). Accessed August 1 2018.

Shin, S. A., Choi, D. S., Kim, C. Y., Han, B. R., Lee, H. D., & Lee, S. C. (2012). The Influence of Raised Heel Insoles on Lower Extremity Joint Kinematics of Young Male During Walking. *Korean Journal of Sport Science*, 23, 232-243. [https://doi.org/10.24985/kjss.2012.23.2.232](https://doi.org/10.24985/kjss.2012.23.2.232)

Snow, R. E., & Williams, K. R. (1994). High heeled shoes: their effect on center of mass position, posture, three-dimensional kinematics, rearfoot motion, and ground reaction forces. *Archives of Physical Medicine and Rehabilitation*, 75, 568-576. [https://doi.org/10.1016/0003-9993(94)90685-8](https://doi.org/10.1016/0003-9993(94)90685-8)

Song, B. H., & Park, J. Y. (2001). The effect of heel-heights on lumbar lordosis for young ladies. *Journal of Korean Society of Physical Therapy*, 13, 613-624.