Determination of Frictional Speeds by Arm Movement and Simulation of Frictional Sounds of Fabrics

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ABSTRACT

This study identified the frictional speeds between the arm and the trunk of a wearer in three different conditions: walking, jogging, and running by motion analysis. To analyze its acoustic properties, we simulated the frictional sounds of fabrics in conditions similar to real life. By analyzing shoulder angles in captured motion pictures, it was identified that the friction between the arm and trunk occurs within 10° of the shoulder angle along the center line of the trunk and the speed of the elbow reached the maximum within the friction range of shoulder angle. The average frictional speeds within 10° were found to be 0.62 m/s at walking, 0.95 m/s at jogging, and 1.78 m/s at running. The frictional sounds of two nylon coated fabrics were generated by these speeds. The noises were simulated based on the frictional speeds and times under three conditions of walking, jogging, and running. We calculated sound characteristics such as the sound pressure levels (SPL) and Zwicker's psychoacoustic parameter. The SPL values ranged from 85 dB at running to 88 dB at jogging, which was about the same noise level as in the busy street. This indicates that the frictional sounds simulated are very loud. The values of loudness(Z) at walking and jogging were higher than that at running, but the fluctuation strength(Z) was increased by walking, jogging, and running, in that order. These results mean that the frictional sounds of fabrics at walking and jogging are noisier and less fluctuating than those at running.

Keywords

Frictional speed, Frictional sound, Fabric, Motion analysis, Acoustic properties

INTRODUCTION

The frictional sound of fabric is generated when a fabric is rubbed against another. It gives us comfort such as pleasant sound color like the rustling sound of silk, but it also gives us discomfort such as annoying sound like the harsh sound of a coated fabric. Especially, the coated fabrics used for a waterproof jacket tend to make much noise, which in some cases bothers not only the wearers but also others. The acoustic property among various textile properties is one of the important factors in evaluating clothing quality (Bishop, 1996). In recent years, several researches have been conducted on fabric sound to meet the increasing consumer's demand in auditory attributes of fabric affecting the clothing comfort.

In the previous studies of fabric sound, the relationship between mechanical properties and sound parameters for various woven fabrics has been investigated to quantify the characteristics of frictional sound (Yi, 2000). The fabric noise is analyzed by cross-sectional shapes of fibers (Kim, 2003), fiber type (Na, 2003), weaves (Kim, 2002) to find out objective factors affecting them. In addition, the subjective sensations and the physiological responses to fabric sounds have been reported (Cho, 2005[1]; Cho, 2005[2]; Cho, 2006). In these researches, they have used a constant frictional speed (0.04 m/s) to generate fabric noises. In fact, the speed was much slower than that occurring in our daily life. Thus the past researches are limited in considering a fabric sound according to speeds of the wearer's activities in various dynamic situations. Recently, Cho et al. (2006) have investigated the changes in acoustic properties of the military uniform by wearer's movement speeds. They found out that loudness (Z) of the fabric noise rapidly increased as the movement's speed increased. That is, fabric sound is closely correlated to the speed and types of movement. However, they did not consider the fact that a practical frictional speed and its fabric sounds are different from a real fabric sound generated by the rubbing between the arm and trunk of a wearer. The motion analysis system can measure and analyze the changes taking place in a human body's motion during walking, jogging, and running. The motion factor can be investigated according to speeds related to clothing friction, and we expect to find out the more accuracy frictional speed of clothing for measuring fabric sound.

The purpose of this study is to conduct a motion analysis to identify the speeds between the arm and the trunk while walking, jogging, and running, to simulate the frictional sound of fabric under conditions similar to real life, and to analyze the acoustic properties of frictional sound of fabric.

EXPERIMENTAL

Motion Analysis for Frictional Speeds of fabrics

Upper-limb motions in three conditions (walking, jogging, and running) on a treadmill were captured by a motion analysis system (Figure 1) to identify the frictional speed between the arm and trunk. Four participants (two males and two females; average age = 26.3, range = 25 ~ 28 years) participated in the experiment and their times were compensated. The speeds of walking, jogging, and running were selected to 1.3

m/s, 2.5 m/s, and 4.5 m/s by referring to the data reported in related papers (Keller, 1996; Minetti, 2003; Niebel, 2003; Emmerik, 2005). To analyze the angle of the shoulder and the speed of the elbow, four markers were attached to the shoulder, elbow, wrist, and pelvis (Figure 2), and their movements were captured by Falcon 240 (Motion Analysis, Santa Rosa: CA, USA) for five seconds for each experimental condition.

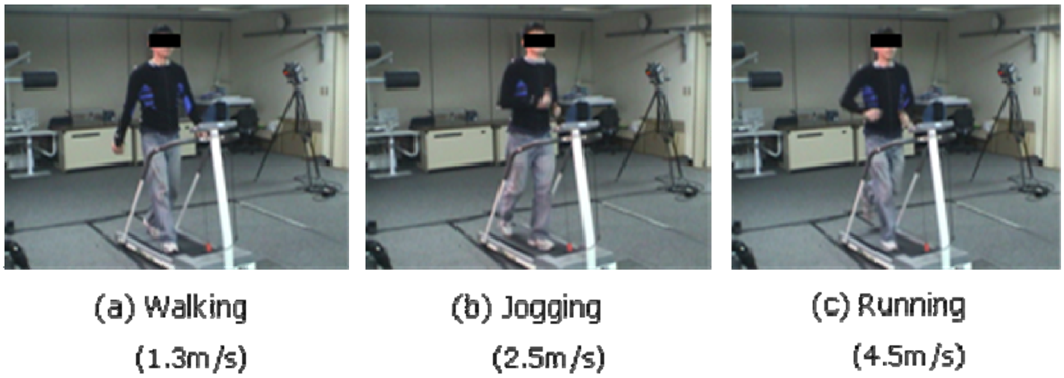


Figure 1. Experiment conditions (speeds)

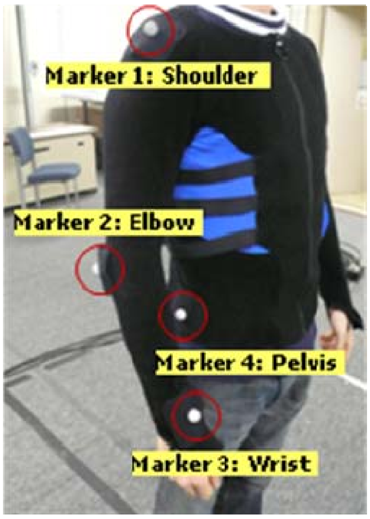


Figure 2. Marker location

Specimens

To compare the acoustic properties of the fabrics according to frictional speeds, two nylon coated fabrics available for a sportswear were selected. The one is finished with a polyurethane(PU) microporous direct dry and milky coating, the other with only a polyurethane microporous direct dry coating. They are made of the same yarn type, density, and weave. Characteristics of the specimens are shown in Table 1.

Table 1. Characteristics of specimens

Speci-men	Fiber content	Finishing	Yarn Type warp/weft	Density Warp x weft	Weave	Thickness (mm)	Weight (g/m^2)
N1	Nylon 100%	PU Microporous Direct Dry Coating, Milky Coating	Filament/ATY+	168 x 53	Plain	1.23	16.73
N2	Nylon 100%	PU Microporous Direct Dry Coating	Filament/ATY	168 x 53	Plain	1.29	14.63

+ATY: Air Textured Yarn

Recording and Analyzing Frictional Sounds of Fabrics

Frictional sounds were generated by Measuring Apparatus for Fabric Noise (MAFN) (Yi, 2002), then they were recorded by Pulse System (Type 7700, B&K) at a soundproof room. Figure 3 shows the diagram of the MAFN. A frictional speed was controlled by changing the weight of the load.

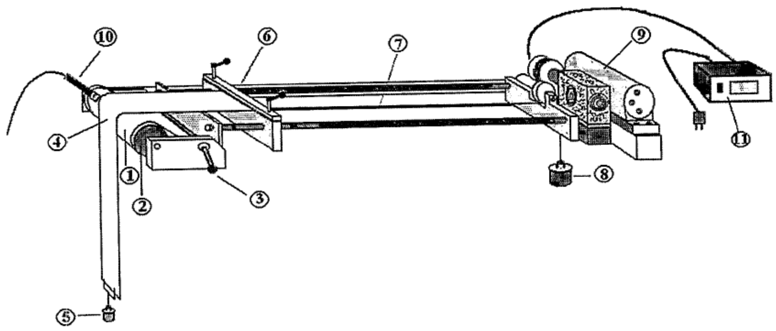


Figure 3. Diagram of MAFN: (1) Fabric, (2) stationary pully, (3) closing lever, (4) fabric 2, (5) load (0.5kg), (6) movable rope, (8) load (9) door closer, (10) microphone, (11) speed meter

The sound spectra were analyzed by the fast Fourier transform (FFT) at frequencies ranging from 0 to 17,350 Hz. Using the Sound Quality System (Type 7698, B&K), we calculated the Sound Pressure Level (SPL), and Zwicker's psychoacoustic parameters of Loudness(Z), Sharpness(Z), Roughness(Z), and Fluctuation Strength(Z) (Zwicker, 1990).

RESULTS AND DISCUSSION

Determination of Frictional Speed according to Various Movements

The average frictional speeds between the arm and trunk at the elbow among the four participants were found to be 0.62 m/s at walking, 0.95 m/s at jogging, and 1.78 m/s at running. By analyzing the shoulder angles and the captured motion pictures, the friction between the arm and trunk was identified to occur within 10° of the shoulder angle along the center line of the trunk, and the speed of elbow reached at maximum within the friction range of the shoulder angle (Figure3). Since the maximum frictional speeds at the elbow varied between arm swings and participants, their averages were calculated for each experimental condition. Table 2 shows the frictional speeds within 10°~10° according to walking, jogging, and running. The frictional speeds determined by this motion analysis were used in generating the fabric sounds in this study.

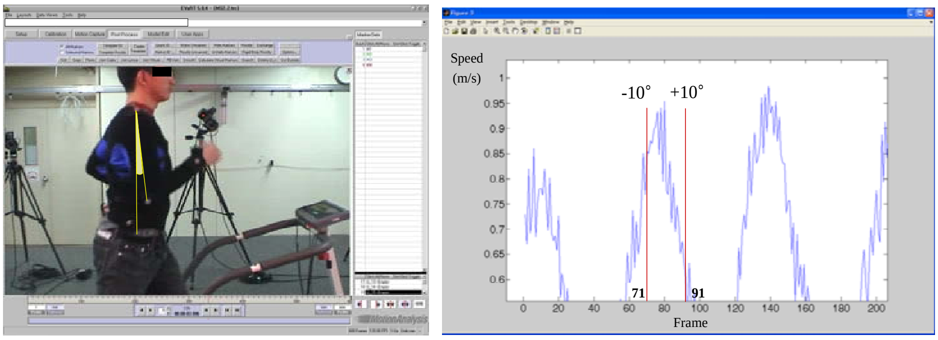


Figure 4. Frictional range (at the shoulder) and speed (at the elbow) analysis

Table 2. Frictional speeds by motion analysis

Ranges of arm movement		-10° ~ +10°		
Wearer's activities		Walking	Jogging	Running
Speed (m/s)	mean	0.62	0.95	1.78
	S.D.	0.17	0.25	0.35

Simulation of Fabric Sound by Frictional Speed

The frictional sounds of each specimen were generated and recorded at three frictional speeds at walking (0.6m/s), jogging (1m/s), and running (1.8m/s). We simulated frictional sounds using the frictional sound and time by measuring the real wearer's activity. Table 3 presents frictional times according to the wearer's activities in motion analysis.

The recording sounds were simulated using the Cooledit (ver. 2.1). The frictional sound was inserted during the friction time within -10°~10° in the middle of all the arm swing times at each condition, respectively. One repeat of the simulating sound consisted of a frictional sound from front to back and one from back to front in the arm swing (Figure 5). One repeat of simulated sound was repeated for 5 seconds in walking, jogging, and running as presented in Figure 6. It shows that the frictional area and time decreased and the frequency of friction increased in the order of walking, jogging, and running.

Table 3. Frictional times by motion analysis

Ranges of arm movement		-10° ~ +10°			All		
Wearer's activities		Walking	Jogging	Running	Walking	Jogging	Running
Time (second)	From front to back	0.09	0.06	0.02	0.36	0.21	0.19
	From Back to front	0.17	0.12	0.05	0.75	0.65	0.49

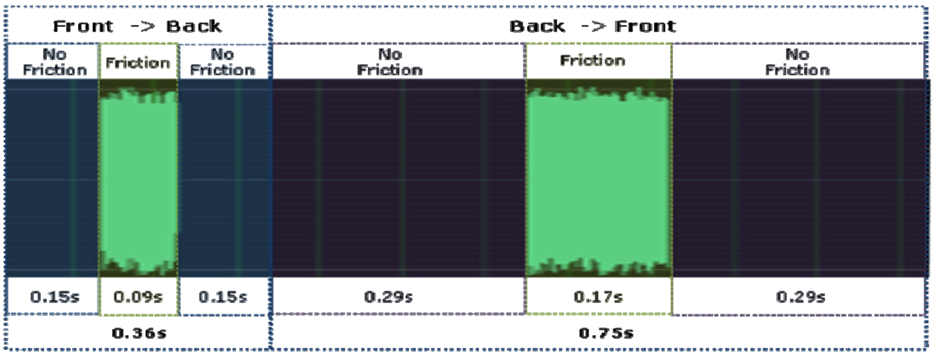
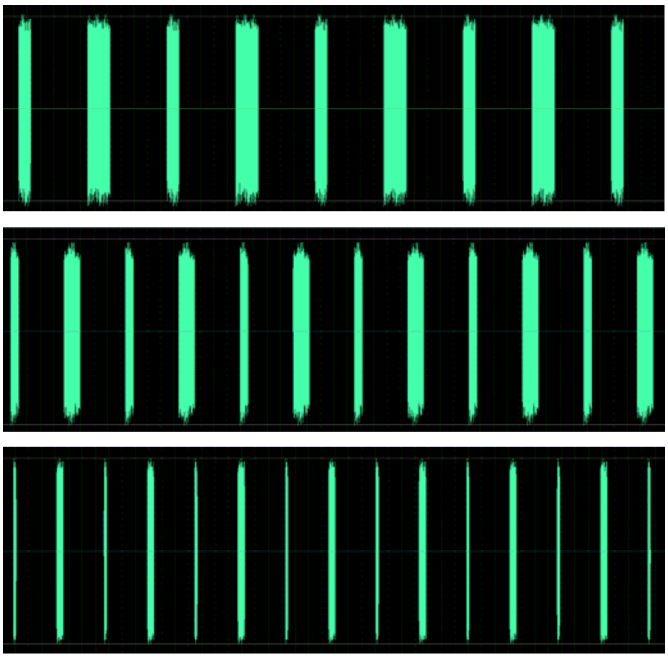


Figure 5. One repeat for simulation of frictional sound according to arm's swing during walking



(a) Walking

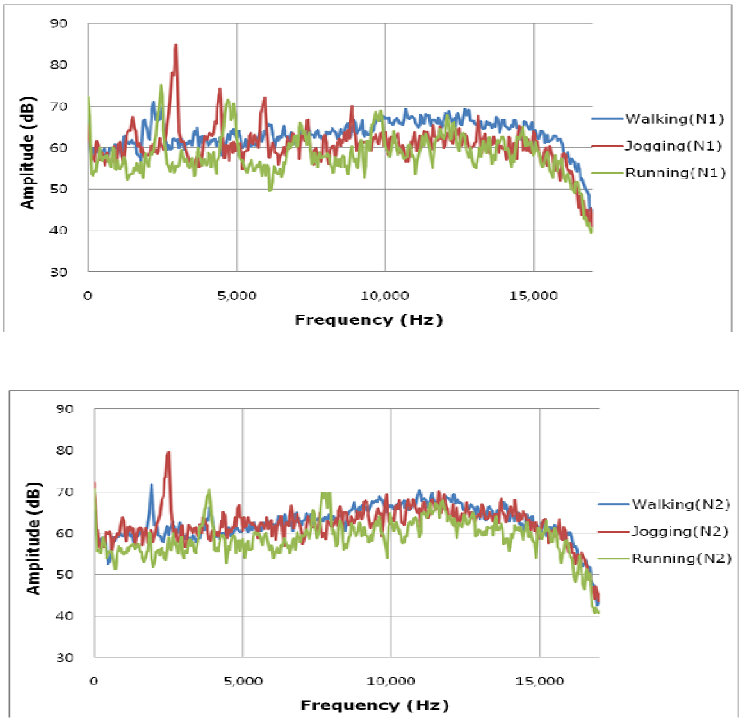
(b) Jogging

(c) Running

Figure 6. Simulation of fabric sound according to wearer's activities

Sound spectra of fabric according to arm movement

The sound spectra of the simulated sounds are shown in Figure 7. The amplitude ranged between 40 dB and 85 dB over the full range of frequencies. The curves of jogging of N1 and N2 showed peak amplitudes of about 3 kHz. The peak of amplitudes of N1 and N2 showed from about 1 kHz to 6 kHz. The simulated fabric sound is more easily recognized in the auditory sensation because the minimal pressure threshold of hearing appeared in the frequency range of 1 kHz to 5 kHz (Kroemer, 1994). The spectrum of N1 was more fluctuating than that of N2 at three conditions. The Spectra of the simulated sound showed fluctuating curves whereas that of the non-simulated sound in the previous studies have not (Yi, 2000; Kim, 2003).



(a) N1

(b) N2

Figure 7. Spectra of frictional sounds according to movement types

Effects of Sound Characteristics at movement types

Figure 8 shows the SPL according to frictional speeds during the wearer's activities. The SPL values ranged from 85dB at running to 88dB at jogging, which is about the same noise level of the busy street. This indicates that the fabric sounds simulated under conditions similar to real life are very loud. The simulated fabric sounds at running weakened and made less noise than at walking and jogging. It is thought that the frictional sounds at running are less loud because of fast frictional speed and short frictional time.

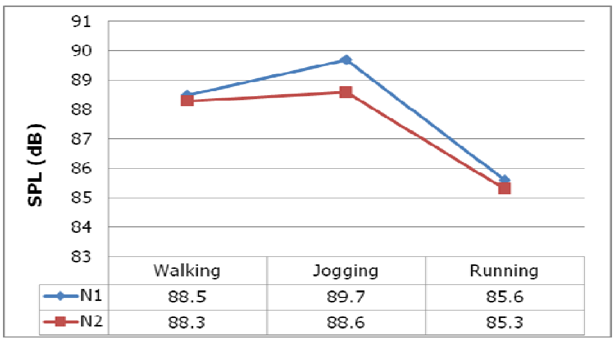
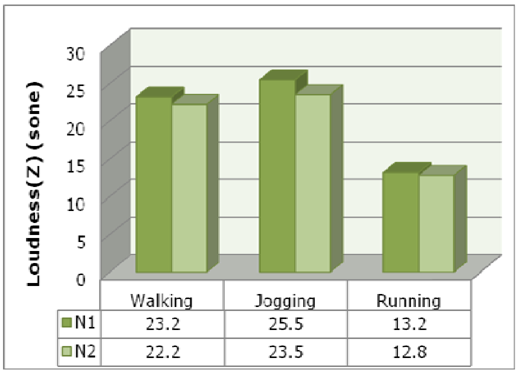
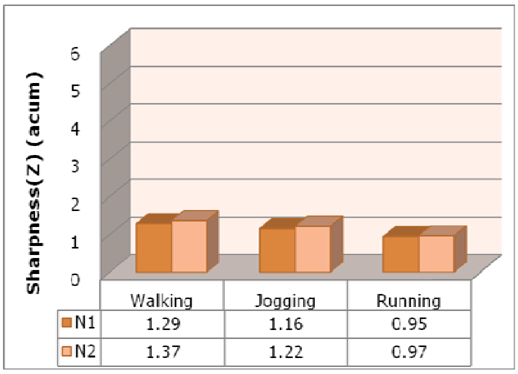


Figure 8. SPL of fabric sound according to wearer's movement types

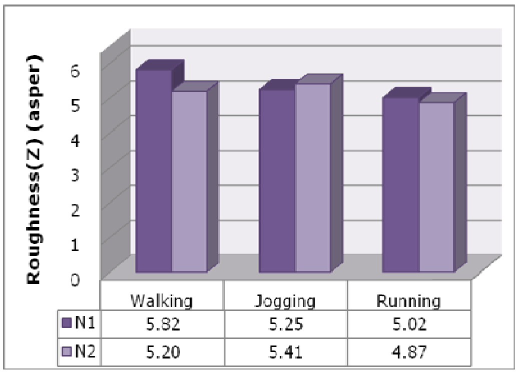
Figure 9 presents Zwicker's psychoacoustic parameters: Loudness(Z), Sharpness(Z), Roughness(Z), and Fluctuation Strength(Z) according to the wearer's activities. The values of loudness(Z) was 22 sone at walking, 24 sone at jogging, and 13 sone at running, which indicate that the clothing noises at walking and jogging are louder than that at running. The values for sharpness(Z), roughness(Z) were about 1 acum and 5 asper, respectively. The values of fluctuation strength(Z) were the same in N1 and N2 at each condition because of the simulated sound by the same method, which increased in the order of walking, jogging, and running.



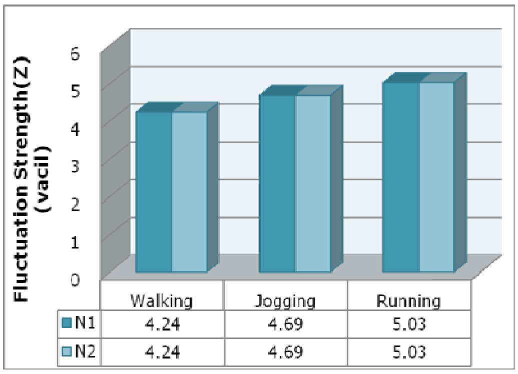
(a) Loudness(Z)



(b) Sharpness(Z)



(c) Roughness(Z)



(d) Fluctuation Strength(Z)

Figure 9. Zwicker's psychoacoustic parameters of fabric sound

CONCLUSIONS

In this study, we developed a method of determining the frictional speeds between the arm and the trunk according the wearer's activities in walking, jogging, and running through a motion analysis. We also analyzed the acoustic properties of frictional sounds by simulating the real frictional sound.

The average frictional speeds recorded through a motion analysis are 0.62 m/s at walking, 0.95 m/s at jogging, and 1.78 m/s at running. The amplitude ranged between 40 dB and 85 dB over the full range of frequencies. The Spectra of the simulated sounds showed fluctuating curves. The SPL values ranged from 85 dB to 88 dB, which indicates that the frictional sounds simulated in conditions similar to real life are very loud. The ranges of loudness(Z) are 22 sone at walking, 24 sone at jogging, and 13 sone at running, which means that our clothing makes more noise when we are walking and jogging than when we are running. The values of sharpness(Z) and roughness(Z)) in three conditions are similar to each other. The values of fluctuation strength(Z) increase in the order of walking, jogging, and running.

The exact frictional speeds identified according to the wearer's activity and the sounds of our clothing identified in this study may be very useful in investigating the subjective sensation or analyzing acoustic properties of clothing noise.

ACKNOWLEDGEMENTS

This work was supported by the Korea Science and Engineering Foundation (KOSEF), grant funded by the Korea government (MOST) (No. R01-2007-000-20745-0).

REFERENCES

Bishop, D. P., 1996, Fabrics: Fabrics and Mechanical Properties, Textile Progress, 26(3)

Cho, G.; Cho, J.; Kim, C.; Ha, J., 2005[1], Physiological and Subjective Evaluation of the Rustling Sounds of Polyester Warp Knitted Fabrics, Textile Research Journal, 75(4), pp. 312-318

Cho, G.; Kim, C.; Cho, J.; Ha, J., 2005[2], Physiological Signal Analyses of Frictional Sound by Structural Parameters of Warp Knitted Fabrics, Fibers and Polymers, 6(1), pp. 89-94

Cho, J.; Cho, G., 2006, Effects of Sound Characteristics of Military Clothing at Different Frictional Speeds on Subjective Sensation, Proceedings of the 2nd International Conference on Clothing and Textile, pp. 72-75

Cho, S.; Yi, E.; Cho, G., 2006, Psychological and Physiological Responses to the Rustling Sounds of Korean Traditional Silk Fabrics, Fibers and Polymers, 7(4), pp. 450-456

Emmerik, R.E.A. Van, 2005, Age-related changes in upper body adaptation to walking speed in human locomotion, Gait & Posture 22: 233–239

Keller, T. S., 1996, Relationship between vertical ground reaction force and speed during walking, slow jogging, and running, Clinical Biomechanics, 11(5), pp. 253-259

Kim, C.; Cho, G.; Yoon, H.; Park, S., 2003, Characteristics of Rustling Sounds Created by the Structure of Polyester Warp Knitted Fabrics, Textile Research Journal, 73(8), pp. 685-691

Kim, C.; Cho, G.; Na, Y., 2003, Effects of the Basic Weave Differences in Silk Fabric and the Yarn Type Variations in Satin Weave on the Sound Parameters, Textile Research Journal, 72(6), pp. 555-560

Kroemer, K. H. E.; Kroemer, H. B.; Kroemer-Elbert, K. E., 1994, Ergonomics: how to design for ease and efficiency, Prentice Hall, N. J.

Minetti, A. E., 2003, A feedback-controlled treadmill (treadmill-on-demand) and the spontaneous speed of walking and running in humans, Journal of Applied Physiology, 95, pp. 838–843

Na, Y.; Cho, G., 2003, Variations in Sensibility to Fabric Frictional Sound by Fiber Type and Subject, Textile Research Journal, 73(9), pp. 837-842

Niebel, B.; Freivalds, A., 1999, Methods, standards, and work design, 11nd ed., McGraw-Hill

Yi, E.; Cho, G., 2000, Fabric Sound Parameters and Their Relationship with Mechanical Properties, Textile Research Journal, 70(9), pp. 828-836

Yi, E.; Cho, G., 2002, A Fabric Sound Evaluation System for Totally Auditory-Sensible Textiles, 72(7), pp. 638-644

Zwicker, E.; Fastle, H., 1990, Psychoacoustics: Facts and Models, Springer-Verlag, Berlin, Germany