

# Guidelines for Selecting the Appropriate Heel Insert for Long-Standing Ladies

Atisthan Wuttimanop, Suchada Rianmora, Mahint Mahattanakorn

**Abstract**—Feet and ankles are parts of human body that receive high-pressure in every day. Feet disorders such as ankle sprain, achilles tendonitis, heel pain, and plantar fasciitis are very common. There are many causes for these feet disorders such as wearing high heels, obesity, sports activity, and standing for a long time. There are many reliefs for feet disorders such as heel insert. However, they come in various shapes and use different materials. There are no specifications in which type is suitable for specific user. This has led to the proposed research to provide guidelines for selecting the appropriate heel insert for ladies who face with long-standing carriers. This research uses contact-measuring techniques to test forces, contact area, and pressure acting on a person's feet in various standing positions with different insert materials and shapes. The proper material for making insert will be presented and discussed.

**Keywords**—Heel inserts, Long-standing person, Contact-data acquisition, Finite element analysis, Ethylene-vinyl acetate (EVA).

## I. INTRODUCTION

FEET and ankles are parts of human body that receive pressure every single day. Feet surface is small comparing to the load it carries. They endure 1.5 times the body weight of a person. Walking, running, or standing for a long period of time often causes feet and ankles pain because of the excessive force applied to those areas. During a typical day, people spend about 4 hours or more on their feet and take 8,000-10,000 steps based on their activity and life style [1], [2].

Feet pain reduces life quality as the person cannot move from one place to another without experiencing the pain. Common feet problems include ankle sprain, Achilles tendonitis, heel pain and plantar fasciitis.

Ankle sprain (Fig. 1 (a)) often occurs in people who participate in sport activities, wear high heels, or step on an uneven surface. It is a result from foot twists, rolls or turns beyond its normal motions and causes injury to tendon and tissue in ankle [3], [4]. Achilles tendonitis (Fig. 1 (b)) is an injury in the heel cord that common in athletes and women. Many sports required lots of muscle strength from legs such as basketball, running, and high jump. Wearing inappropriate shoes will cause the condition to get worst. Women who wear high heels often experience Achilles tendonitis because high heels stretch Achilles tendon, allowing it to get inflamed easily [5]–[7]. Heel pain (Fig. 1 (c)) is often found in women who are about 50–60 years old. The pain experienced is associated to bone tendon inflammatory. The pain is caused by

doing activities such as running, jumping or standing for extended period of time, especially in shoes that do not fit well. People, who are over-weight, have huge body, or small heels post higher risk in developing heel pain [8], [9]. Plantar fasciitis (Fig. 1 (d)) occurs because of activities overload on feet. These can happen from jogging, climbing, walking, or standing on hard floor for a long period of time. People who are over-weight, have flat plantar, or walk in wrong position have high risk to obtain pain from plantar fasciitis [10], [11].

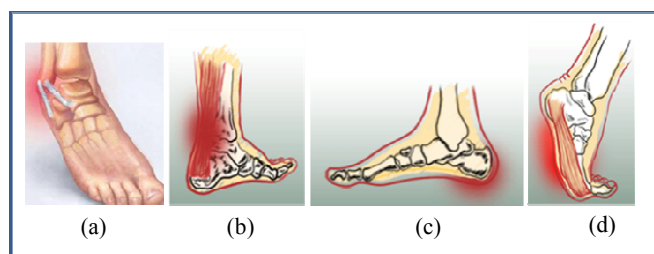


Fig. 1 Foot problems, (a) ankle sprain, (b) achilles tendonitis, (c) heel pains, (d) plantar fasciitis [12]

Many researches on feet pain prevention and reduction have been done. One technique to reduce feet pain is to use heel inserts [10]. Heel inserts are designed to hold the heel in alignment and therefore spread the pressure throughout the feet evenly, reducing excessive force over one area.

## II. RESEARCH BACKGROUND

The finite element analysis (FEA) concept has been developed for estimating the internal pressure of the human bone at the area of interests [13]. In the preliminary studies, FEA has been applied for determining which material and shape of the inserts can distribute pressure the best. After obtaining 3D CAD model from reverse engineering process where the 3D laser scanner with handheld was applied, the load distributed on the insert presented through the simulation of FEA. Illustrated in Fig. 2 were the steps required for simulating load distribution on the insert with containing silicone gel was used to demonstrate the FEA application. The difficulty of this simulation depends on selecting the appropriate properties of the material which were approximately selected from the provided library function. Since the components of ingredients of the inserts are not exactly provided, so the information filled into the program might contain some errors or mistakes.

S. Rianmora is with Sirindhorn International Institute of Technology, Thammasat University, Klong Luang, Pathumthani, Thailand (corresponding author to provide phone: (66-2)5643221-9, e-mail: suchada@siit.tu.ac.th).

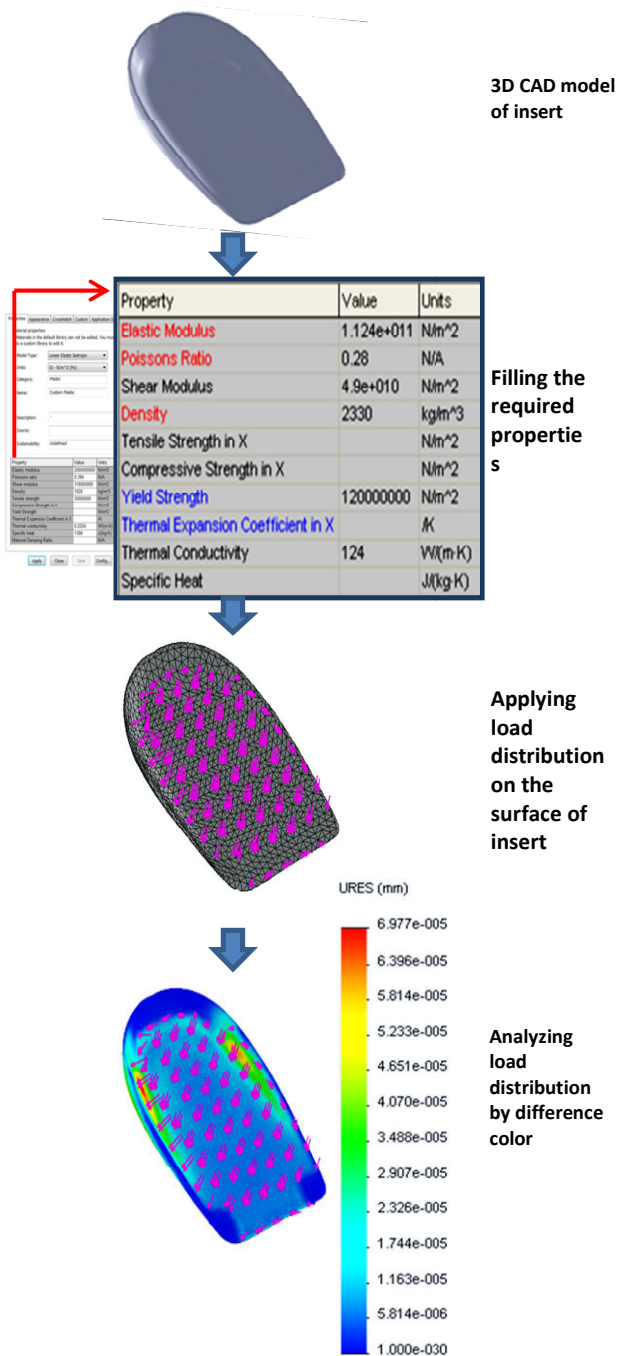


Fig. 2 The steps of finite element analysis (FEA)

However, the difficulties of this FEA method are filling the required properties of the insert material, since ingredients of the inserts are not exactly provided. In practice, the physical properties (e.g., elastic modulus, shear modulus or density) have been guessed to assign in the FEA applications. The results obtained (e.g., load distribution) are applied as just an idea for selecting the insert. It would be better to test the load distribution directly from the feet rather than randomly selecting and assigning the load on the virtual model of insert.

### III. RESEARCH DESCRIPTIONS

In order to accomplish the objective of the research, the work habits that cause feet disorders, types and shape of the inserts that are available in the market, and postures during working have been focused. In the market, inserts are varied in shape, size and material where the majority design is asked for supporting shoes. For long-standing lady, flat-cut shoes style is mostly selected as shown in Fig. 3.



Fig. 3 Lady's flat-cut shoes [14]

The data of a specific target group that has the following:

- *Normal feet:* The subject in focus will be on the normal feet since the majority of people have this type of feet.
- *Female age between 25-30 years:* This is because wearing improper shoes such as high heels caused most of foot disorders in young adults. Hence, selecting young females that do not normally wear heels higher than 2.5 cm as the target group for this research is suitable.
- *Average weight (48-52 kg):* This is because obesity will also cause feet disorders. People with average weight are suitable, as the stress on their feet will not be affected by their weight.
- *Never had fatal accidents that could affect stress on their feet:* They should also do not have any feet disorder previously.

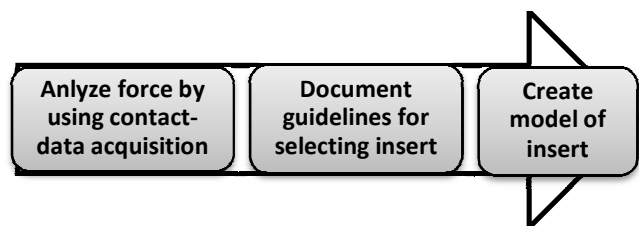


Fig. 4 The steps of proposed research

Tek-Scan uses paper-thin load cell to measure force, contact area and contact pressure. During testing, a movie can be recorded for up to 8 seconds or 400 frames when a load is applied to the load cell. From the movie, each frame can be chosen in the software for the analysis as shown in Fig. 5 (b). Within each frame, the force, contact area and contact pressure were recorded.

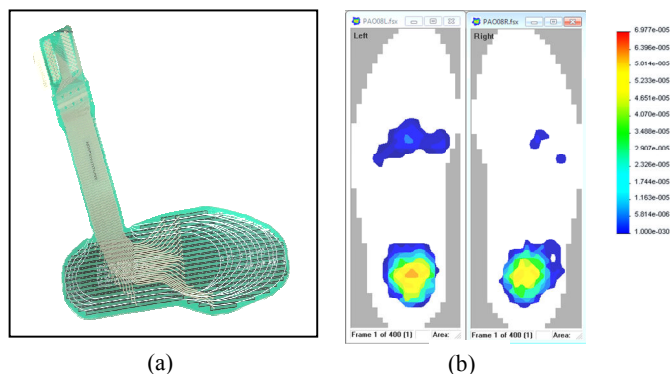


Fig. 5 (a) Load cell used, (b) simulation of force on the load cell

The load cell shown in Fig. 5 (a) is a full sized load cell. To use it, cutting the load cell into the size of the tester's shoe size is required. Cutting the load cell is very time consuming, as it requires very high accuracy in order to keep the maximum amount of sensors for the test.

In addition to cutting the load cell into shape, calibration process is required before the test. For the calibration process, the tester must stand still on each foot for about 5 seconds at a time as shown in Fig. 6 (a).

During the calibration step, the software may return calibration error, which will not allow us to continue to the actual experiment. Errors during calibration process may come from tester unable to balance on one feet, the load cells were not cut into a perfect shape or design problem of the load cell itself. During the calibration process that returned errors, it was noticed that one of the problems was that even when the right foot was raised, there were still forces and pressure occurred around the bending region of the load cell of the raised foot. This was a design flaw of the equipment as switching from left's side to the right still returns the same calibration error. This means that the load cell has only sensor on one side. When bending it on the left foot, the sensor on the load cell contracts. However, when bending it on the right foot, the sensor stretches, which caused the problem.

Conduct experiments on test subjects using Tek-Scan to determine the force acting on their feet. The experiment will be done in three standing positions.

- 1) *Standing upright*: This position represents the standing position for occupations such as soldier where they need to stand arm by their side for a long time as shown in Fig. 6 (b).
- 2) *Standing with arms bending about 45 degree*: This position represents the standing position for occupations such as dishwasher in a restaurant where they need to put their hands in front of the body inside the sink as shown in Fig. 6 (c).
- 3) *Standing with arms about perpendicular to the body (90°)*: This position represents the standing position for a factory assembler who is required to assemble parts in front of them on a conveyor as shown in Fig. 6 (d).

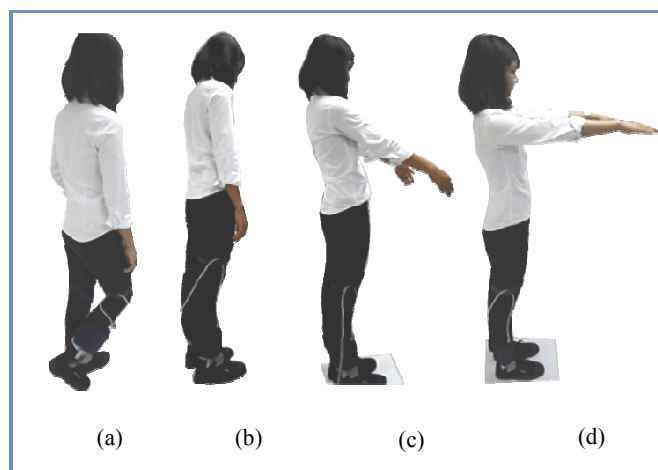


Fig. 6 Postures of volunteer in experiment, (a) calibrating posture, (b) standing upright (Arm by side), (c) standing with arms bending 45°, (d) standing with arms about perpendicular to the body (90°)

The experiment will be done on six difference types of inserts.

1. Gel and rubber with cloth on top
2. Natural latex foam
3. Silicone gel
4. Gel with cloth on top
5. Soft foam
6. Invisible gel



Fig. 7 Specimen 1 (gel and rubber with cloth on top)



Fig. 8 Specimen 2 (natural latex foam)



Fig. 9 Specimen 3 (silicone gel)



Fig. 10 Specimen 4 (gel with cloth on top)



Fig. 11 Specimen 5 (soft foam)



Fig. 12 Specimen 6 (invisible gel)

The specimens that are used in the experiment for this research are shown in Figs. 7 to 12. After the experiments, the best shape and material of the heel insert that has the lowest pressure can be determined.

To document guidelines for selecting the appropriate heel inserts, after obtaining the results from Tek-Scan shape, and the material used to produce foot inserts for long-standing people is made.

For research contribution, after documenting the guidelines, all the analyzed results will be used to design a new model of insert that would be able to reduce fatigue for long-standing people most effectively.

#### IV. RESULTS AND DISCUSSIONS

Pressure results from the Tek-Scan test are shown in Table I. The variations of the pressure depend upon the force distributions and the contact areas. The results of this pressure are used to determine the trend for which type of insert is the best. In average, by considering the pressure on both left and right feet, the lowest pressure was resulted from specimen 5 (63.67 KPa for the left foot, and 52.67 KPa for the right foot), then specimen 6, (69.33 KPa for the left foot, and 56.67 for the right foot) respectively. The lowest pressure resulted from specimen 5, then specimen 6, specimen 3, specimen 2, specimen 4, and specimen 1, respectively.

When comparing the pressure and arm position, we can see that Specimen 6 had the lowest pressure when the arm position was at 0°. However, at 45° and 90°, Specimen 5 (Soft foam) was the best as shown in Fig. 13.

TABLE I  
 RESULTS OF PRESSURE FROM TEK-SCAN

Insert Type	Approx. arm position with respect to body	Pressure (KPa)					
		Beginning		2 Second		Average	
		Left	Right	Left	Right	Left	Right
Specimen 1 (Gel and rubber with cloth)	0°	155.00	108.00	120.00	93.00	110.00	82.00
	45°	154.00	125.00	114.00	105.00	121.40	100.80
	90°	164.00	144.00	136.00	113.00	122.00	90.00
Specimen 2 (Latex foam)	0°	167.00	117.00	129.00	92.00	129.00	95.00
	45°	155.00	101.00	110.00	76.00	97.00	81.00
	90°	153.00	100.00	106.00	75.00	98.00	71.00
Specimen 3 (Silicone gel)	0°	134.00	111.00	109.00	77.00	95.00	79.00
	45°	145.00	69.00	116.00	59.00	109.00	52.00
	90°	149.00	87.00	118.00	71.00	112.00	65.00
Specimen 4 (Gel with cloth)	0°	155.00	125.00	133.00	101.00	124.00	96.00
	45°	159.00	109.00	127.00	75.00	117.00	73.00
	90°	171.00	121.00	142.00	88.00	129.00	81.00
Specimen 5 (Soft foam)	0°	79.00	67.00	62.00	53.00	62.00	52.00
	45°	74.00	75.00	68.00	60.00	62.00	56.00
	90°	86.00	78.00	70.00	62.00	67.00	50.00
Specimen 6 (Invisible gel)	0°	79.00	69.00	63.00	53.00	56.00	52.00
	45°	99.00	79.00	80.00	60.00	77.00	60.00
	90°	95.00	72.00	77.00	61.00	75.00	58.00

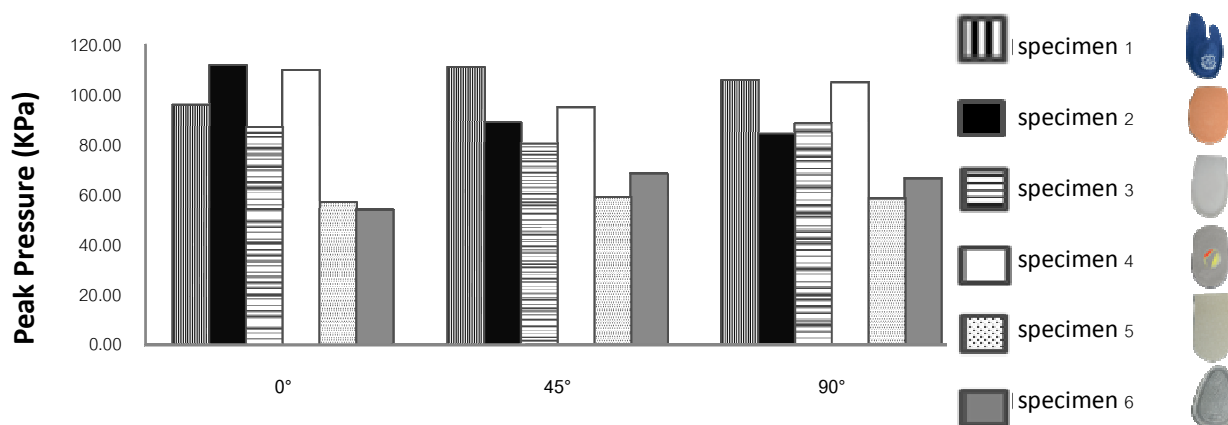


Fig. 13 Graph showing results of pressure from Tek-scan

### V. CONCLUSIONS

It is suspected that soft foam provides the best results because the pressure can quickly distribute over a large area. Having the shape similarly to the specimen 5 (Fig. 14) has the trend to provide the best support in order to reduce fatigue for long standing lady who wears flat-cut shoes. The specimen 5 (Soft foam) also had the highest contact area. This is due to the softness of soft foam that allows the insert to form into the shape instantly.



Fig. 14 Specimen 5 (soft foam)

For research contribution, after documenting the guidelines, all the analyzed results will be used to design a new model of insert that would be able to reduce fatigue for long-standing people most effectively.

Polyurethane (PU) also has similar properties with specimen 5 (Soft foam) [15], [16]. It is also more durable than Ethylene-vinyl acetate (EVA). However, PU is more expensive.

EVA is cheap and it can provide comfort just as good as specimen 5 [17]. It can be cut into the shape as heel inserts (Fig. 15).

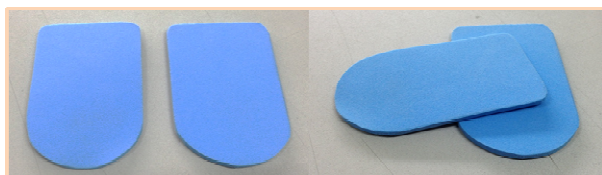


Fig. 15 EVA cut into heel shape

Additionally, visiting a real work industry such as slaughterhouse or factories to observe the actual work behavior of the operators can make more benefits to imitate their actions in the tests and not limiting to just long-standing

people [18].

### ACKNOWLEDGMENT

This research has been financially supported by Bangchak Petroleum PCL, and Thammasat University (Young researcher fund). Tek-Scan device is supported by Faculty of Physical Therapy, Mahidol University, Thailand.

### REFERENCES

- [1] University of Maryland Medical Center (UMMC), "Foot pain – Introduction", online [http://www.umm.edu/patiented/articles/what\\_foot\\_pain\\_000061\\_1.htm](http://www.umm.edu/patiented/articles/what_foot_pain_000061_1.htm), 2011.
- [2] K. Brückner, S. Odenwalda, S. Schwanitz, J. Heidenfelder, and T. Milanib, "Polyurethane-foam midsoles in running shoes - impact energy and damping". The journal of procedia engineering, vol. 2, issue 2, 2010, pp. 2789-2793.
- [3] American College of Foot and Ankle Surgeons (ACFAS), "Ankle Sprain", online <http://www.foothealthfacts.org/footankleinfo/ankle-sprain.htm>, 2009.
- [4] B. D. Den Hartog "Insertional achilles tendinosis: pathogenesis and treatment", Foot and ankle clinics, vol. 14, issue 4, 2009, pp. 639-650.
- [5] C. T. Hu, and A.S. Flemister, "Insertional achilles tendinopathy: surgical options", Operative techniques in Orthopaedics, vol. 18, issue 4, 2008, pp. 247-253.
- [6] A. McMillan, and C. Payne, "Immediate effect of foot orthoses on plantar force timing during running: A repeated measures study", The foot, vol. 21, issue 1, 2011, pp. 26-30.
- [7] F. Benazzo, A. Todesca, and L. Cecilian, "Achilles' tendon tendinitis and heel pain", Operative techniques in sports medicine, vol. 5, issue 3, 1997, pp. 179-188.
- [8] D. R. Bonanno, K.B. Landorf, and H.B. Menz, "Pressure-relieving properties of various shoe inserts in older people with plantar heel pain", Gait and posture, vol. 33, issue 3, 2011, pp. 385-389.
- [9] G. Lichtwark, and A. Wilson, "In vivo mechanical properties of the human Achilles tendon during one-legged hopping", The Journal of Experimental Biology, vol. 208, 2005, pp. 4715-4725.
- [10] A.K. Ramanathan, M.C. John, G.P. Arnold, L. Cochrane, and R.J. Abboud, "The effects of off-the-shelf in-shoe heel inserts on forefoot plantar pressure", Gait and posture, vol. 28, issue 4, 2008, pp. 533-537.
- [11] L. Yung-Hui and W. Hsien, "The effects of off-the-shelf in-shoe heel inserts on forefoot plantar pressure", Applied Ergonomics, vol. 36, issue 3, 2005, pp. 355-362.
- [12] Drug information online, "Heel Pain", online <http://www.drugs.com/health-guide/heel-pain.html>.
- [13] "The effects of off-the-shelf in-shoe heel inserts on forefoot plantar pressure".
- [14] W.P. Chen, C.W. Ju and F.T. Tang, "Effect of total contact insoles on the plantar stress redistribution: a finite element analysis", Clinical Biomechanics, Elsevier, vol. 18, 2003, pp. S17-S24.
- [15] Jen, "Honey Kennedy", online <http://www.honeykennedy.com/2013/03/>.

- [16] N. J. Mills, C. Fitzgerald, A. Gilchrist, and R. Verdejo, "Polymer foams for personal protection: cushions, shoes and helmets", *Composites Science and Technology*, vol. 63, 2003, pp. 2389–2400.
- [17] D. G. Dikobe and A. S. Luyt, "Morphology and properties of polypropylene/ethylene vinyl acetate copolymer/wood powder blend composites", *Express Polymer Letters*, Vol.3, No.3, 2009, 190–199.
- [18] R Verdejo, and N. J. Mills, "Heel–shoe interactions and the durability of EVA foam running-shoe midsoles". *The journal of biomechanics*, vol. 37, Issue 9, 2004, pp. 1379-1386.

**A. Wuttimanop** is a master student in Logistics and Supply Chain Systems Engineering Program, Sirindhorn International Institute of Technology, Thammasat University, Thailand. She received B.Eng. from King's Mongkut University of Technology North Bangkok, Thailand. Her email address is <awuttimanop@gmail.com>.

**S. Rianmora** is a lecturer in School of Manufacturing Systems and Mechanical Engineering, Sirindhorn International Institute of Technology, Thammasat University, Thailand. She received her D.Eng from Asian Institute of Technology, Thailand. Her research interests are Reverse Engineering and Rapid Prototyping. Her email address is <suchada@siit.tu.ac.th>.

**M. Mahattanakorn**, He received B.Eng from Sirindhorn International Institute of Technology, Thammasat University, Thailand. His research interests are Finite Element Analysis and Reverse Engineering. His email address is <mahint88@gmail.com>.