Nail clipper ergonomic evaluation and redesign for the elderly

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Abstract

This study designs and evaluates a new nail clipper for the elderly using ergonomic methods. The nail clipper usage problems and requirements were collected first. After requirement analysis we applied ergonomic simulation in redesigning the nail clipper and developing a pedal plate. A usability test was conducted to evaluate both typical and newly developed nail clippers using 20 elder participants. The dependent measures were the total number of nails clipped, completion time and discomfort and satisfaction subjective ratings. The experimental results indicated that the newly developed nail clipper was superior to the typical one in subjective ratings for discomfort and satisfaction. The performance of the newly-developed nail clipper is similar to that of the typical clipper. Some important nail clipper design implications for the ageing population are discussed.

Keywords: Ageing; Product design; Usability; Computer simulation.

Relevance to industry

With the increase in the elderly population, problems caused by aging have gradually emerged. Aging may cause the elderly inconvenience in using many household objects that are not specifically designed for the elderly. Therefore, industrial designers should try to redesign household objects to enhance living quality for the elderly. This study used nail clipper design as an example to show how to apply ergonomic methods in product design.
1. Introduction

The average life expectancy of human beings has increased yearly due to rapid progress in medicine and technology. However, the birthrate in some advanced countries has decreased (Economist, 2010). There is now an ever increasing proportion of elderly in the national population. Taking Taiwan for example, the proportion of elderly in the population was 10.4% in 2008. It is estimated that the proportion of elderly will increase to 14% by 2017 and to 20.1% by 2025. It takes approximately eight years to transform an aging society to a super-aging society, suggesting that the speed of population aging in Taiwan is increasing (Council for economic planning and development, 2008). The problems caused by aging have also gradually emerged in Taiwan. The phenomenon of population aging is not only common in Taiwan, but has serious influence in many developed countries around the world.

Aging is usually accompanied by physical function decline, i.e., physical inconvenience, such as reduced muscle endurance, joint stiffness and decreased activity. (Harma, 1996). The disability prevalence in activities of daily living (ADL) and instrumental activities of daily living (IADL) increases with age as well. For IADL, cooking, cutting toenails and doing housework, the functional disability rate rise sharply with the increase in age for Chinese elderly (Tang et al., 1999). Moreover, a high prevalence of foot problems had been reported among aging adults with most of them unable to care their own feet (Ebrahim and Sainsbury, 1989). All of these changes may cause the elderly inconvenience in using many household objects that are not specifically designed for them. Therefore, ergonomists should try to redesign household objects to enhance living quality for the elderly.

If aging problems and requirements can be considered in household object design, the elderly can be made more comfortable at home. Taking the nail clipper as
an example, it is more difficult for the elderly to clip their own nails compared with young adults (Wu and Hou, 2009). Hand pinch strength decreases with aging and the finger and toe nails of the elderly become thicker, harder and more dry (Tsai, 2002). Based on the previous investigation (Wu et al., 2012), most respondents (81.7%) used the “two-point pinch” to clip their fingernails. The thumb and forefinger were the major parts experiencing discomfort. In toenail clipping the patient’s neck and lower back were the major parts experiencing discomfort. These are the main problems for the elderly in clipping their nails. In order to resolve these problems this study focused on designing a proper nail clipper for the elderly.

The main purpose of this study is to design a new nail clipper that can be used easily and comfortably by the elderly. The ergonomic principles for good design (Stanton, 1998) and computer simulation technology were applied to amend the inappropriate postures of traditional nail clipping, thus, further avoiding discomfort and pain to the fingers, wrist, neck or lower back. The specific expectations of this study are as follows: (1) to reduce over-bending in the wrist and lumbar vertebra during nail clipping and (2) to prevent the elderly from feeling discomfort during nail clipping.

2. Collecting nail clipping postures

2.1. Typical nail clipping postures

To understand the nail clipping postures assumed while using a traditional nail
clipper, the posture of 24 elders’ was photographed while clipping their finger and toenails. No strict regulations were imposed on the subjects, allowing them to cut their nails freely. Based on the collected photographs, three categories of nail clipping postures were identified. They are two-point pinch, lateral pinch and grasping hold, as shown in Figure 1. ‘Two-point pinch’ means using front thumb to press the nail clipper and the forefinger and thumb to hold the nail clipper. Performing the two-point pinch when using a nail clipper is the most frequent posture. ‘Lateral pinch’ implies placing the nail clipper above the forefinger, middle finger, ring finger and little finger, and using the thumb to press the nail clipper, where the knife edge and the exterior of the little finger are in the same direction. ‘Grasping hold’ means placing the nail clipper on the palm and using the little finger, ring finger and middle finger to press, where the knife edge and the exterior of the little finger are in the same direction.

We classed the postures of the 24 individuals into three categories for toenail clipping: leg-crossed posture, sole-supinated posture and sole-pronated posture, as shown in Figure 2. ‘Leg-crossed posture’ means crossing the lower leg onto the thigh of other leg to clip nails, with the leg placed horizontally. ‘Sole-supinated posture’ implies supinating the sole, turning aside the body to cross the elbow over the knee, and stepping the sole forward. This was the most frequent used posture when clipping
toenails. ‘Sole-pronated posture’ means lifting up the leg, crossing the elbow on the
same side over the thigh, and pronating the sole to lift the toes.

2.2. Ergonomic simulation of nail clipping

After collecting these nail clipping postures we used JACK 4.0 software to
simulate the representative nail clipping postures (according to the above collected
photographs) and analyze the joint angles of the wrist, neck and back. The purpose of
computer-aided ergonomic evaluation was to understand how large the joint angle
was away from the neutral position and to redesign the nail clipper for preventing the
large joint angle. Figure 3 shows the representative nail clipping postures and their
simulation results. The dimensions of virtual humans were based on Taiwanese
female adults’ average anthropometric data. The chair height was set a little lower
than the average knee popliteal height of Taiwanese female adults. The typical nail
clipper was also established for ergonomic simulation in the JACK virtual
environment. Table 1 shows the target joint angles under representative nail clipping
postures when using a traditional nail clipper. It was obvious that wrist ulnar/radial
deviation was about 24.8~36.6 degree during clipping hand nails and toenails. In
order to prevent the wrist from ulnar/radial deviation, the structure of the traditional
nail clipper should be redesigned. Suppose that we can grasp a traditional nail clipper
with a neutral wrist, it is impossible to clip the nails because the cutter edge is not
consistent with the nail edge, as simulated in Figure 4(a). Therefore, a design idea of
changing the cutter direction came from the simulation results. Further, it is inevitable
that the torso reclined 23.5~37.8 degree while clipping toenails (see Table 1). To
design a proper pedal plate for clipping toenails may be a good idea to improve the
back bending problem. All these ideas were expected to enables users less bending angles in wrist and back during nail clipping as much as possible.

3. Designing a new nail clipper

3.1. Ergonomic principles for hand tools

The nail clipping motion involves wrist twist and pinch strength, including ulnar deviation or stretching. Shih and Ou (2005) conducted a study on the influence of three wrist postures on pinch strength and found that, regardless of the subject’s gender, pinch strength is the strongest when performing a neutral motion, followed by bending and stretching. Further, Jansen, et al. (2003) compared the differences in pinch strength between pinch types and forearm postures. Three pinch types, namely, the key pinch/lateral pinch, the fingertip/two-point pinch and the three-jaw chuck pinch/three-point pinch were compared under neutral, pronated and supinated forearm postures. When performing the three-point pinch motion the forearm posture does not have a significant influence on pinch strength. However, when performing the lateral pinch or a two-point pinch motion the forearm posture has a significant influence on pinch strength. Regardless of the pinch types, the strongest pinch strength originates from the neutral forearm posture, which is consistent with the conclusion reached by Halpern and Fernandez (1996). The least pinch strength originates from the lateral pinch motion. The least two-point pinch strength resulted when the arm is pronated. Therefore, it is important to maintain the neutral forearm posture while using a nail clipper.

The pinch distance may also influence the nail clipping pinch strength. Imrhan and Rahman (1995) indicated that the pinch distance has a significant effect on pinch
strength when the distance is within 2-9.2 cm. The study also found that if the pinch
distance is more than 9.2 cm, some individuals may fail to complete the pinching
motion because their fingers are not long enough. This finding is consistent with the
suggestion that the largest hand-tool handle should have a width of 8.8 cm, as
proposed by Dababneh, et al. (2004). Greenderg and Chaffin (1997) found that when
pinch distance is 2.3-3.5 in most individuals can perform the largest strength pinching
motion. This finding can be applied in designing the nail clipper handle.

3.2. Nail clipper framework design

A previous study (Emanuel, et al, 1980) indicated that the bending angle between
all tools/sports equipment and the handle should be 19°±5° for more natural wrist
posture. Several scholars investigated the design concept for hand tool slant angle.
Konz indicated in 1986 that a hammer handle slant angle of 10° is helpful to users
(Konz, 1986). All of these suggestions are aimed at maintaining a neutral wrist when
using a hand tool. Based on the simulation results mentioned earlier, in order to
maintain a neutral wrist the knife angle should be 114° between the handle and
normal line to the cutter edge (see Figures 4(a) and 4(b)). Grasping styled handles are
proposed here for clipping the nails with the power-grasp posture, as shown in Figure
4(c). This is because “power-grasping” can produce the most strength when using a
hand tool. However, most people adopt the “two-point pinch” when using a typical
nail clipper. This is because the handle of a typical nail clipper is linear and thin,
which is not suitable for grasping.

3.3. Nail clipper handles design
Because the fingers are directly contacting the handles, if the handles are excessively hard, such as steel, the users may feel uncomfortable. Soft materials were added to the nail clipper handles, with a larger contact surface for the fingers. The addition of a friction surface can reduce slipping caused by handle materials. Therefore, an outer plastic layer was attached to the newly developed nail clipper to increase friction with a foam layer attached to the original steel surface to disperse the pressure between the fingers/palm and the handle. As opposed to using steel as the contact surface in typical nail clippers, friction and softness was added to the surface of the newly developed clipper.

The material contact surface is associated with the comfort level when using a nail clipper. Although a grooved design conforming to the finger surface enables users to feel comfortable, the single grooved-size fails to conform to all various sized fingers. The contact surface grooved design also generates strong pressure on the contact surface as a result of the stretching action caused by inappropriate groove design depth (Mital and Karwowski, 1991). A smaller grooved design can offer greater friction to prevent fingers from slipping (Institute of occupational safety and health, 1997). Therefore, designed the nail clipper handles with a smaller grooved design.

4. Designing a pedal plate

The major discomfort during toenail clipping was experienced by the neck and lower back (lumbar vertebra). This phenomenon reveals that discomfort may be experienced from the excessive bending angle in the neck and lumbar vertebra during toenail clipping. A pedal plate was therefore designed for toenail clipping to reduce users’ lumbar angle. The JACK software was used to simulate the most appropriate
bending angles for the ankles and foot sole. According to the simulation results the forward and lateral angles of the pedal should be set at 35° and 12°, respectively (see Figure 5).

In order to fit various body heights the highest point of the pedal plate was referred to the knee height of Taiwanese adults aged 45-65. The adjustable pedal height was designed in the 358 and 413 mm range. A prototype of the designed pedal plate was also made in this study.

5. Usability test

5.1. Participants of the test

An experiment was conducted here to compare the usability of the typical nail clipper and the newly-developed one. A total of 20 elderly individuals (10 females and 10 males), participated in the experiment. The dominant hand of all subjects was the right hand. The average age of the male subjects was 71.5 ± 6.9, while that of females was 72.9 ± 9.4. All participants could clip their nails without help from others. The subjects were paid for their participation.

5.2. Procedure of the test

Before the test each participant signed a copy of the informed consent and was asked not to clip his/her nails for two weeks. Each participant was given instruction on the clipping postures for using the two tested nail clippers before the test, as shown in Figure 6. The experimental trials were conducted in an ergonomic laboratory at a university. In order to balance the experimental procedure for using the two nail
clippers, 20 participants were randomly assigned to two groups (named A and B). Each group had five male and five female participants. Figure 7 shows the experimental procedure for these two Groups. Group A used the newly-developed nail clipper to clip the left hand nails and left toe nails first, and then used typical nail clipper to clip right the hand nails and right toe nails. In contrast, Group B used the typical nail clipper to clip the left hand nails and left toe nails first, and then used the newly-developed nail clipper to clip the right hand nails and right toe nails. After using the typical nail clipper or the newly-developed nail clipper, the subjects were requested to rate their subjective discomfort and satisfaction. The experiment was conducted under the premise that all of the hand nails and toenails had to be completely clipped at one time.

5.3. Data collections in the test

Participants were tested individually. The whole nail-clipping process was recorded on digital video during the experiment. All of the hand nails and toenails had to be completely clipped during one experimental trial. The number of nails clipped and the completion time were collected by analyzing the video after each experimental trial. After all of the nails were clipped the subject was requested to rate their discomfort level on 12 body parts. ‘0’ represents no discomfort; ‘1’ represents a little discomfort; ‘2’ represents somewhat discomfort; ‘3’ represents very discomfort; ‘4’ represents extreme discomfort. Subjective reports of discomfort have been associated with pain, tiredness, soreness and numbness and are related to biomechanical and fatigue factors (Cascioli et al., 2011; Reid et al., 2010). Because the proposed nail clipper had good cutter direction and soft grasping styled handles, we expected it would lead to less discomfort level in the wrist and fingers.
The participant was also asked to rate their satisfaction with the two tested nail clippers along three dimensions: ease of clipping, no slipping and clipper size. Each dimension had a five-point Likert scale, with 1, 2, 3, 4, and 5 representing ‘very unsatisfactory’, ‘not satisfactory’, ‘acceptable’, ‘satisfactory’, and ‘very satisfactory’, respectively. When the rating score was greater, the satisfaction level of that dimension was better.

5.4. Test results

Because no significant gender differences were found in the ratings and objective results, we pooled the male and female data together for the following statistical analysis. The number of clippings and completion time for the two tested nail clippers are shown in Table 2. No significant differences (p<0.05) were found in the number of clippings and completion time between the typical nail clipper and the newly-developed one. This result indicated that the newly-developed nail clipper had similar performance to the typical clipper.

Table 3 shows the subjective discomfort ratings for using the two tested nail clippers. For all body parts, the mean discomfort rating for the newly developed nail clipper was less than that for the typical nail clipper. The newly developed nail clipper resulted in significantly less discomfort (p<0.05) in the neck, shoulder, lower back, wrist, thumb, index finger and middle finger, compared with the typical nail clipper. The newly developed nail clipper with the knife angle and the grasping-styled handle design could be used easily with a neutral wrist posture. The extra friction and softness added to the handle of the newly developed clipper made the users more comfortable. All of these design characteristics caused less discomfort around the
wrist, thumb and hand, as reported by the participants. Moreover, using the pedal plate resulted in less forward flexion in the head and back, thereby reducing discomfort in the neck, shoulder and lower back.

Table 4 shows the satisfaction rating score results for the two nail clippers. The mean score for ‘ease of clipping’ for the typical nail clippers was 3.70, while that for the newly developed clipper was 4.45. In addition, significant $p=0.003$ was obtained from the nonparametric two-related-samples test (Wilcoxon test), indicating that the participants considered using the newly developed nail clipper significantly easier than the typical nail clipper. The mean score of ‘no slipping’ were significantly higher ($p<0.05$) for the newly developed nail clipper (2.90) than that of the typical one (1.95). In other words, the typical nail clipper was considered to slip significantly easier than the newly developed one.

Discomfort and satisfaction ratings were the only significant differences between the two designs. These significant differences in subjective ratings could have been caused by the knife angle, grasping-styled handle, as well as extra friction and softness added to the newly developed clipper. Previous researchers indicated that the improvement in subjective rating could have been caused by the Hawthorn effect (Chi and Lin, 2009; Fostervold, et al., 2001). The Hawthorne effect was defined as a confounding and biasing factor in intervention research that resulted from research participation (status or participants difference in perception) (Austin and Davies, 2007). In this study, the Hawthorn effect might also contributed to the subjective comfort rating results, although the participants were asked to honestly respond with their comfort and satisfaction level. Further study taking extensive time to repeat the same experiment is required to test the Hawthorne effect. Since the subjective discomfort is directly associated with posture, force exertion and local pressure, more studies with objective measures are necessary to investigate whether using the new
developed nail clipper really causes less discomfort.

6. Conclusions

This study applied a computer-aided ergonomic simulation in redesigning a finger nail/toe clipper nail clipper. The new handle shape design enables the elderly to clip their own nails using a power-grasp posture instead of the pinch posture. The proposed nail clipper can increase the user’s manual operating strength when clipping nails. The other characteristic of this new nail clipper is modified cutter direction that enables users to easily clip nails while using a neutral wrist posture that provides better ergonomic hand/arm postures. The usability test results showed significantly less neck, shoulder, lower back, wrist, thumb, index finger, and middle finger discomfort while using the proposed device compared with the typical nail clipper. Users reported the proposed nail clipper was significantly easier to use in clipping nails than the typical clipper. Because no measures were taken to control for the Hawthorn effect in the current usability test, the reported significantly better comfort ratings could not be wholly attributed to the new nail clipper design. More studies are required to confirm whether using the new developed nail clipper really causes less discomfort.

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Figure captions

Figure 1. Three categories of nail clipping postures
Figure 2. Three categories of toe nail clipping postures
Figure 3. The representative nail clipping postures were simulated using JACK software
Figure 4. New nail clipper design based on simulation data
Figure 5. The toenail clipping simulation results used for designing the auxiliary pedal plate
Figure 6. Usage posture comparison between the two tested nail clippers
Figure 7. The nail clipping test procedure diagram

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Table 1. Simulation results of the representative nail clipping postures when using a traditional nail clipper
Table 2. Number of clipping and completion time when using the two tested nail clippers
Table 3. Subjective ratings of discomfort for using two tested nail clippers
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Figure 1. Three categories of nail clipping postures

(a) Two-point pinch  (b) Lateral pinch  (c) Grasping hold
Figure 2. Three categories of toe nail clipping postures
Figure 3. The representative nail clipping postures were simulated using JACK software.
(a) Design idea coming from simulation of holding a supposed nail clipper with a neutral wrist.

(b) The knife angle was designed as $114^\circ$ between the handle and normal line to the cutter edge.

(c) The grasping-styled handles was designed for power-grasping.

Figure 4. New nail clipper design based on simulation data.
Figure 5. The toenail clipping simulation results used for designing the auxiliary pedal plate.
(a) The typical nail clipper is used by two-point pinch posture

(b) The newly-developed nail clipper is used by power-grasping posture

Figure 6. Usage posture comparison between the two tested nail clippers
Figure 7. The nail clipping test procedure diagram

**Group A**
- (5 males, 5 females)
  - Use the **newly-developed nail clipper** to clip left hand nails and left toe nails with the **pedal plate**
  - Rate subjective discomfort and satisfactory of the **newly-developed nail**
  - Use the **typical nail clipper** to clip right hand nails and right toe nails
  - Rate subjective discomfort and satisfactory of the **typical nail clipper**

**Group B**
- (5 males, 5 females)
  - Use the **typical nail clipper** to clip left hand nails and left toe nails
  - Rate subjective discomfort and satisfactory of the **typical nail clipper**
  - Use the **newly-developed nail clipper** to clip right hand nails and right toe nails with the **pedal plate**
  - Rate subjective discomfort and satisfactory of the **newly-developed nail**
Table 1
Simulation results of the representative nail clipping postures when using a traditional nail clipper

<table>
<thead>
<tr>
<th></th>
<th>Simulation in Figure 3(b)</th>
<th>Simulation in Figure 3(d)</th>
<th>Simulation in Figure 3(f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head flexion</td>
<td>30.1°</td>
<td>2.0°</td>
<td>2.9°</td>
</tr>
<tr>
<td>Palmar flexion</td>
<td>15.2°</td>
<td>17.1°</td>
<td>19.1°</td>
</tr>
<tr>
<td>Wrist ulnar/radial deviation*</td>
<td>-36.6°</td>
<td>-24.8°</td>
<td>+31.9°</td>
</tr>
<tr>
<td>Torso recline</td>
<td>6.3°</td>
<td>23.5°</td>
<td>37.8°</td>
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</table>

* - means ulnar deviation and + means radial deviation
Table 2

Number of clipping and completion time when using the two tested nail clippers

<table>
<thead>
<tr>
<th></th>
<th>Number of clipping (Mean ± SD)</th>
<th>Completion time in seconds (Mean ± SD)</th>
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</thead>
<tbody>
<tr>
<td><strong>Clipping hand nails</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical nail clipper</td>
<td>27.10 ± 6.30</td>
<td>83.12 ± 24.24</td>
</tr>
<tr>
<td>Newly developed nail clipper</td>
<td>26.50 ± 6.60</td>
<td>90.21 ± 25.57</td>
</tr>
<tr>
<td>t-test for the two clippers</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td><strong>Clipping toenails</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typical nail clipper</td>
<td>24.70 ± 5.40</td>
<td>74.23 ± 23.70</td>
</tr>
<tr>
<td>Newly developed nail clipper</td>
<td>24.90 ± 5.50</td>
<td>83.21 ± 23.19</td>
</tr>
<tr>
<td>t-test for the two clippers</td>
<td>NS</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS: Not significant different at $\alpha = 0.05$
Table 3
Subjective ratings of discomfort for using two tested nail clippers

<table>
<thead>
<tr>
<th>Body Part</th>
<th>Subjective Ratings of discomfort</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Typical nail clipper (Mean ± SD)</td>
<td>Newly developed nail clipper (Mean ± SD)</td>
</tr>
<tr>
<td>Neck</td>
<td>0.85 ± 0.93</td>
<td>0.10 ± 0.45</td>
</tr>
<tr>
<td>Shoulder</td>
<td>0.45 ± 0.89</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Upper back</td>
<td>0.20 ± 0.52</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Lower back</td>
<td>0.85 ± 1.04</td>
<td>0.05 ± 0.22</td>
</tr>
<tr>
<td>Arm</td>
<td>0.10 ± 0.31</td>
<td>0.05 ± 0.22</td>
</tr>
<tr>
<td>Wrist</td>
<td>0.75 ± 0.97</td>
<td>0.15 ± 0.49</td>
</tr>
<tr>
<td>Thumb</td>
<td>0.85 ± 0.88</td>
<td>0.10 ± 0.45</td>
</tr>
<tr>
<td>Index finger</td>
<td>0.75 ± 0.91</td>
<td>0.05 ± 0.22</td>
</tr>
<tr>
<td>Middle finger</td>
<td>0.20 ± 0.41</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Ring finger</td>
<td>0.10 ± 0.31</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Little finger</td>
<td>0.05 ± 0.22</td>
<td>0.00 ± 0.00</td>
</tr>
<tr>
<td>Palm</td>
<td>0.35 ± 0.67</td>
<td>0.10 ± 0.45</td>
</tr>
</tbody>
</table>

*p<0.05 by Wilcoxon Symbo grade test
Table 4
The results of satisfaction rating score for the two nail clippers

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Typical nail clipper</th>
<th>Newly developed nail clipper</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of clipping</td>
<td>3.70 ± 0.66</td>
<td>4.45 ± 0.69</td>
<td>0.003*</td>
</tr>
<tr>
<td>Not to slip</td>
<td>1.95 ± 1.10</td>
<td>2.90 ± 0.72</td>
<td>0.013*</td>
</tr>
<tr>
<td>Clipper size</td>
<td>3.50 ± 0.69</td>
<td>3.50 ± 0.69</td>
<td>1.000</td>
</tr>
</tbody>
</table>

*P<0.05 by Wilcoxon symbol grade test