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Development of a Chair Preventing Low Back Pain with Sitting Person Doing Hand Working at the Same Time

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Abstract – One reason of low back pain (LBP) is remaining one's posture for long time especially while sitting on a chair. Rocking chair can create swing when sitting person press the floor at his feet then his posture somewhat changes but one can't do hand working like typing, writing, and assembling while swinging by present rocking chair. This paper's purpose is making a chair that prevents low back pain and can do hand working at the same time. Through experiments of three types of chairs, we made hypothesis of the conditions in which people can do hand working. We made a monopod rocking chair that meets the conditions. The monopod rocking chair's swing is not so comfortable for one's back, so we made new swing model which is caused by one's breath and controlled by one's toes. We made monopod rocking chair of logs that meets the model and patients sat on the chair for two hours with hand working. Then LBP didn't arise and we could do typing without problem. We found it is effective for LBP patients to do hand working for long time on the chair.

Index Terms – Low back pain, Rocking chair, Swing model, Abdomen

I. Introduction

Out of all 291 conditions studied in the Global Burden of Disease 2010 Study, LBP ranked highest as years lived with disability, and sixth as disability-adjusted life years (DALYs). The global point prevalence of LBP was 9.4% (95% CI 9.0 to 9.8). DALYs increased from 58.2 million (M) (95% CI 39.9M to 78.1M) in 1990 to 83.0M (95% CI 56.6M to 111.9M) in 2010. Prevalence and burden increased with age [1]. In Japan, Ministry of Health, Labour and Welfare said LBP ranked highest as illness or injury that person has subjective symptom to but also said about 85% of LBP, source of pain was not found [2]. So present treatment is not completely effective. There are many preventive measures that people believe effective with statistics, patient's feeling, or hypothesis and so on.

There is a research that says high sitting time was positively associated with high LBP [3]. Another research says when back muscle works to keep one's posture, load on his back becomes larger so back muscle may cause LBP [4]. The other research says electromyograms showed some patients of LBP used back muscles continuously under conditions that healthy people don't use those muscles [5]. From those researches, we thought patients of LBP uses back muscles to keep their posture while sitting on a chair so they feel LBP.

We suppose remaining one's posture for long time causes LBP. That is similar to pressure sore which is often caused while remaining one's posture in a bed. Against pressure sore, posture change or vibration is encouraged as the treatment [6]. So we think the treatment, posture change or vibration, may have similar effect to low back pain.

Rocking chair can create both posture change and vibration by swing when sitting person press the floor at his foot. The swing's frequency is near 1 Hz so that's different to the best frequency of pressure sore, that is 45 Hz. However, posture is changing while swinging and traditionally exercise is encouraged to prevent LBP so we think a rocking chair has some effect to prevent LBP. However, present rocking chairs can't swing while hand working like typing, writing, and assembling because the person's head and hand moves too much while swinging. The person must stop the swing to type and LBP is coming. In fact, a research says sitting in combination with whole body vibration and awkward posture like using agriculture machine seems to have the strongest association with the presence of LBP [7]. So our purpose is to make a chair that prevents LBP and can do hand working at the same time.

II. Basic Examination Of Three Types Of Chairs

We made three types of chairs to find what conditions are needed to get our purpose. First we made hanging arms and head chair (Fig.1). That hangs arms and a head on boards that are connected with ropes. We thought ropes would cause swing of body and the sitting person can do hand working at the same time because arms and head can move in horizontal plane freely. However, when we sat on the chair, we must have stopped our body while hand working. When arms moved with rope, our body tried to move forward. Low back muscle must have contracted strongly to stop body then LBP came. We thought the reason is that when bones push joints, the forces have horizontal components so our body moves forward (Fig. 2 and Fig.3).

Then arms, head and abdomen can't stop the forward movement because those move freely in horizontal plane. As the result, low back must contract all the time to stop the forward movement. We thought we have to stop forward movement without low back muscle's contraction. Second we made rolling upper body chair (Fig.4). That has rolling board on which sitting person lays down his body and the roll is controlled by pushing the floor at his foot. We thought the rolling movement is like rocking chair's swing and forward

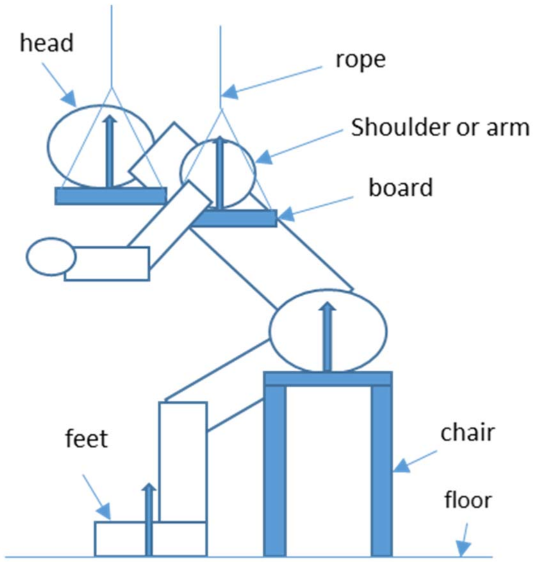

Fig.1 hanging arms and head chair

F_1 Force that upper bone pushes the joint

F_2 Force that lower bone pushes the joint

mg gravity

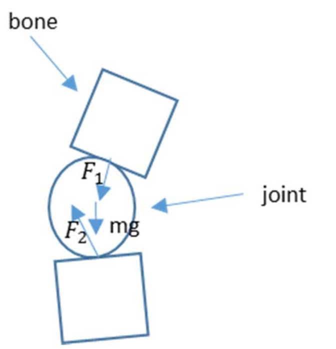

Fig.2 forces to a bone

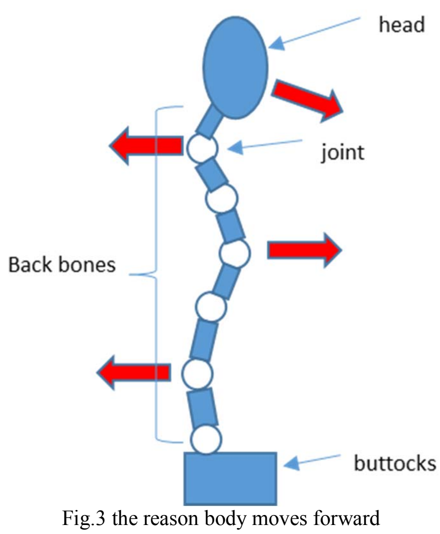

Fig.3 the reason body moves forward

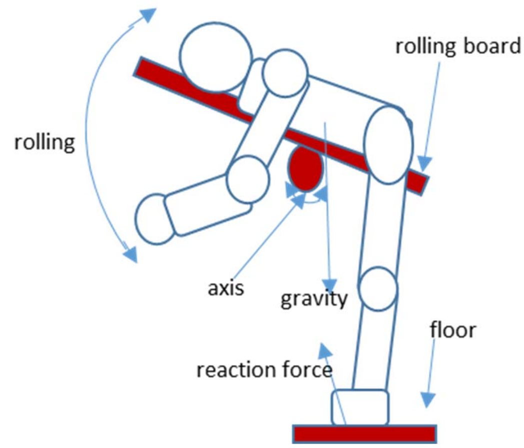

Fig.4 rolling upper body chair

movement which is caused by back bones was stopped by board without low back muscle's constriction because all upper body lies on the board. As we thought, the rolling was comfortable like rocking chair and forward movement didn't occur so we could do hand working at the same time. However, rolling person had pains in his abdomen and head that contacted with the rolling board. We put a cushion on the board then the pain somewhat lowered but at the same time, rolling person couldn't do hand working. We thought the reason is that cushion deforms greatly and that causes body's movement which can't be controlled by pushing floor. Then we thought we have to reduce the pain without a cushion.

Third we made monopod rocking chair (Fig.5). That has a monopod which contacts with a flat plate so sitting person rolls with using contact point of the monopod to the plate as fulcrum then the rolling is controlled by his feet pushing the plate. That also has two boards as backrest and abdomen rest. Compared to rolling upper body chair, monopod rocking chair can roll near vertical angle and sitting person contact with backrest and abdomen rest alternately. So we thought rolling person has no pain. However, when we sat on the chair, rolling person had pains in his abdomen, back and buttocks that contacted with ends of boards even if we cut the ends to make them round. Also, low back muscle got tired when we were rolling long time and that caused LBP. Then we thought places where sitting person contacts must have big radius of curvature and rolling must be slow and also rolling must have rest like rolling upper body chair.

III. Detailed Examinatio Of Monopod Rocking Chair

From three types of chairs, we got hypothesis of the conditions in which sitting person prevent LBP and he can do hand working at the same time. One, movement that is caused by inner force of backbones must be resisted by pushing something that is hard enough unlike cushion. Two, swing needs rest and should move slowly like rolling upper body chair. Three, places where sitting person contacts must have big radius of curvature.

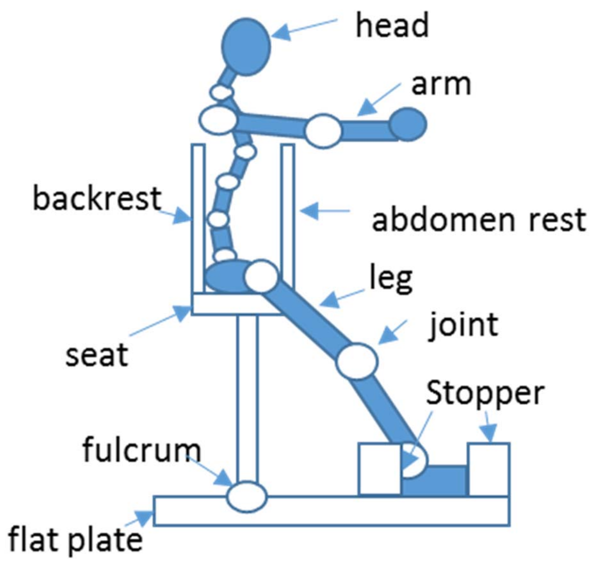

Fig.5 monopod rocking chair

To meet three conditions, we made new monopod rocking chair (Fig.6). That has logs instead of boards about abdomen rest, backrest, seat, stopper of feet and monopod. Before that, we sat or leaned on the logs and confirmed that we didn't have pains so we thought radius of curvature would be big enough. Log's bottom is circle so we thought sitting person would be able to rest. Logs are heavier than boards so we thought swing would go slowly enough. Then three conditions would complete.

Patients sat on the chair for two hours with typing, writing, and cutting paper. As the result, LBP didn't occur, they could do hand working without problem, places where sitting person contacts had little pains that he could neglect enough. However, the swing was somewhat uncomfortable and low back muscle got tired slowly.

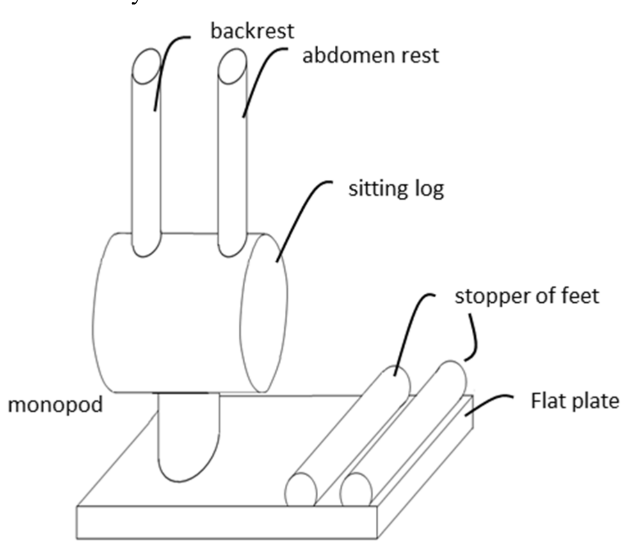

Fig.6 new monopod rocking chair

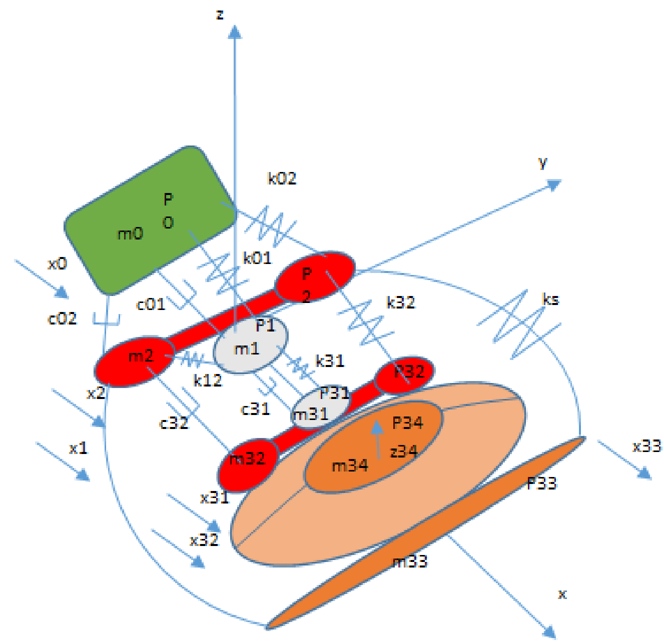

Fig.7 new swing model

We thought swing should be bigger, more stable and less energetic about low back muscle. Then we found breath could cause swing when expansion of abdomen pushes backrest and abdomen rest. We tried the swing then we felt the swing was more stable and less energetic especially about low back muscle. We also found when swing was controlled by one's toes, the swing might become bigger. We also found when radius of curvature of backrest and abdomen rest was smaller, swing might become bigger.

We made new swing model (Fig.7) and analyzed it to explain those expectations and to find the most efficient swing.

Fig.6 is cross-section from abdomen skin to backrest. In this model, backrest (P0), back bones (P1), back muscles (P2), and abdomen muscles (P3i) move in x direction and those are symmetric about x-z plane but only a part of abdomen muscles that gets touched with stomach and lungs above (P31) moves in z direction. This model is mostly spring mass damper system. In Fig.6, xi means axial displacement about x direction of Pi, kij means spring from Pi to Pj, mi means mass of Pi, and cij means damper from Pi to Pij. Here kij and cij works only while pushing except k01 (pushing and pulling) and ks (only pulling). When x_0 , x_1 , x_2 , x_{3i} , z_{34} are 0, springs are natural length.

Abdomen muscles move like pistons with water (Fig.8). P3i has piston and water. Pistons move as keeping whole volume of water then areas are S (P31), aS (P32), (a+1)S (P33), bS (P34). Mass of P3i changes when water push or pull pistons by product of water density, piston area and piston travel distance. Although not shown in Fig.7, there is a piston P34 that moves in z direction and this piston express breath with external force.

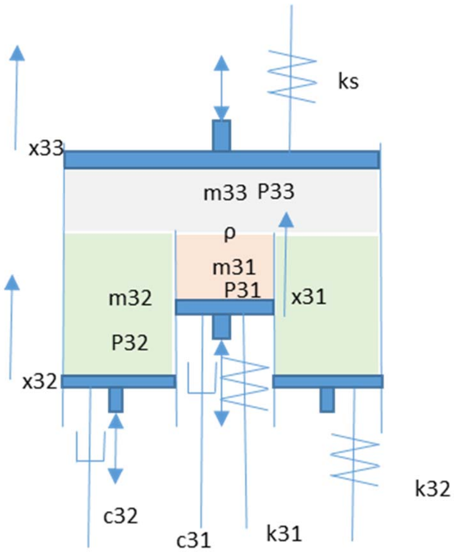

Fig.8 image of abdomen muscles

Here fi means external force of Pi.

$$x'' = \frac{d^2x}{dt^2}, x' = \frac{dx}{dt}.$$

Equation of motion about P0, P1, P2 are

$$m_0x_0'' = -c_{01}(x_0' - x_1') - k_{01}(x_0 - x_1) - c_{02}(x_0' - x_2') - k_{02}(x_0 - x_2) + f_0 \quad (1)$$

$$m_1x_1'' = -c_{31}(x_1' - x_{31}') - k_{31}(x_1 - x_{31}) + f_1 + c_{01}(x_0' - x_1') + k_{01}(x_0 - x_1) - k_{12}(x_1 - x_2) \quad (2)$$

$$m_2x_2'' = -c_{32}(x_2' - x_{32}') - k_{32}(x_2 - x_{32}) + c_{02}(x_0' - x_2') + k_{02}(x_0 - x_2) + k_s(x_{33} - x_2) + k_{12}(x_1 - x_2) + f_2 \quad (3)$$

Momentum equation about P3i are

$$m_{31(t+dt)}x_{31}'_{(t+dt)} + k_p dt = m_{31}x_{31}' + d1dt \quad (4)$$

$$m_{32(t+dt)}x_{32}'_{(t+dt)} + ak_p dt = m_{32}x_{32}' + d2dt \quad (5)$$

$$m_{33(t+dt)}x_{33}'_{(t+dt)} + -(a+1)k_p dt = m_{33}x_{33}' + d3dt \quad (6)$$

$$m_{34(t+dt)}z_{34}'_{(t+dt)} + -bk_p dt = m_{34}z_{34}' + d4dt \quad (7)$$

Here

$$d1 = c_{31}(x_1' - x_{31}') + k_{31}(x_1 - x_{31}) + f_{31}$$

$$d2 = c_{32}(x_2' - x_{32}') + k_{32}(x_2 - x_{32}) + f_{32}$$

$$d3 = -k_s(x_{33} - x_2) + f_{33}$$

$$d4 = -m_{34}g + f_{34}$$

and k_p means product of abdominal pressure P and S.

To analyze one collision between backrest and back, we gave 1 m/s to P0 as initial value and 0 m/s to others. We didn't know appropriate value of mi, ki, ci, fi so those value were our prospects and this analysis would have large error.

First, we changed mass of m_0 to 1, 5, 20 kg and got change of acceleration of P2 (Fig.9).

As the result, the max value of acceleration became bigger as mass of m_0 increased. We felt acceleration became bigger then too so that meats.

Second, we changed k_{02} and C_{02} to 0 (N/m) and 0 (Ns/m), 500 and 30, 5000 and 300. We wanted to express rate of pushing back bone and back muscle by this. When we only push back bone, k_{02} and C_{02} are 0 and 0. When k_{02} and C_{02} are bigger, rate of pushing back muscle becomes bigger too. When k_{02} and C_{02} are 500 and 30, this analysis pushes back bone and back muscle about same rate. Then we got change of acceleration of P2 (Fig.10). As the result, pushing only backbone is similar to pushing backbone and back muscle about same rate. When k_{02} and C_{02} becomes ten times bigger, initial acceleration is max value and the acceleration decay to near 0.

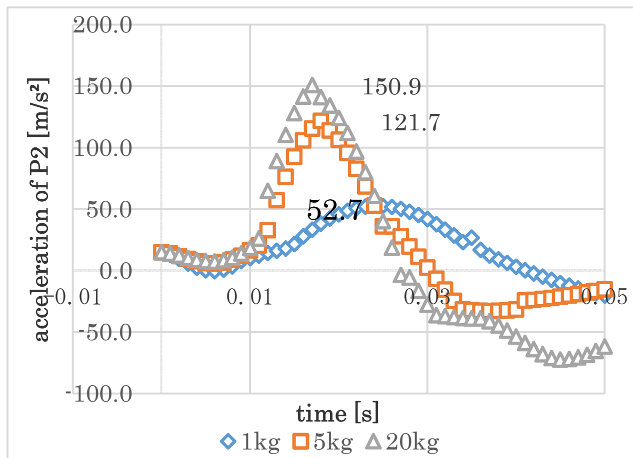

Fig.9 m0 value and change of acceleration

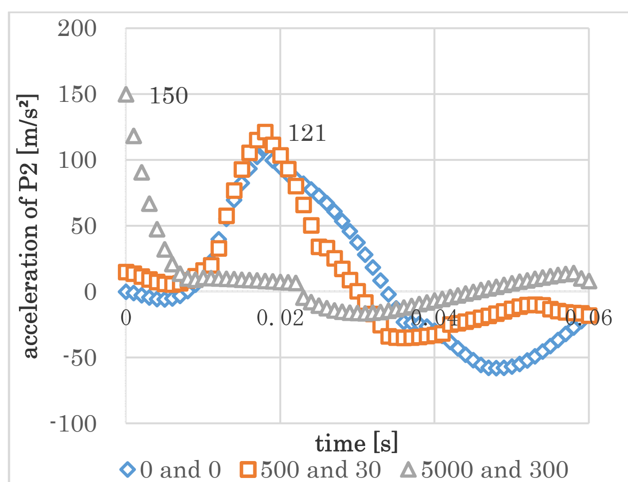

Fig.10 pushing rate and change of acceleration

There were many problems that Fig.9 and Fig.10 didn't show our feelings. First, we felt swing and our breath had similar vibration. Second, when backrest push only backbone, back muscle had biggest acceleration. Third, swing becomes slower as backrest's mass increase. However, this model shows passive movement mostly about mass, spring and damper so if we didn't have active action of the nerve, our body might move like this model.

IV. CONCLUSIONS

Through experiments of three types of chairs, we got hypothesis of the conditions in which sitting person prevent LBP and he can do hand working at the same time. One, movement that is caused by inner force of backbones must be resisted by pushing something that is hard enough unlike cushion. Two, swing needs rest and should move slowly like rolling upper body chair. Three, places where sitting person contacts must have big radius of curvature. Monopod rocking chair of logs may meet those conditions. Patients sat on monopod rocking chair of logs for two hours with hand working. Then LBP didn't occur by their feeling and they could do hand working at the same time.

New swing model showed that when backrest is heavier, back muscle acceleration becomes bigger. The model didn't show breath's vibration, swing vibration, and rate of pushing back that man feel most comfortable though we expected those are important.

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