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Biomechanical Analysis with the Force of Deltoid Muscle for Pianist

Dong-Ok Shin[1]* and Seung-Houn La[2]

[1]Department of Industrial Engineering, University of Central Florida
[2]Department of Industrial & Systems Engineering, Myong ji College
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Abstract : This study presents the relationship between the height of the chair and the force of deltoid muscle for pianist. The subject simulated playing the piano on the three different heights of the chairs. Digital camera was used to determine the angle of the joint of shoulder and elbow for 2- dimensional static link segment modeling in the sagittal plane. The deltoid, biceps and triceps muscles were considered to determine the muscle load. The results, compared to the force of deltoid muscle, are that the downward position of the higher chair produces significantly large force than the other two lower chairs. It can be caused by hunched shoulder with decreasing deltoid angle. In case of the upward position caused by the lower chair, even though the smallest force of deltoid presented, it was increased the force of elbow.

Key Words : Biomechanical evaluation, Deltoid muscle, pianist

1. Introduction

Playing the piano is a very high risked repetitive work. For example, when the performer plays "Chopin, Ballad #3 in A flat Major", he or she touches the keyboard with their right hand almost 1426 times in 7-10 minutes. Repetitive stress injuries bring misery to pianists. Most stress injuries of the hand, wrist, arm and shoulders involve the tendons.

Dr. Hao huang (1998), mentioned if piano player sit too low, their fingers will labor under the burden of static arm weight: if performer sits too high the playing often becomes rigid and non-nuanced, with accompanying tension in the wrist and shoulders.

So far, many different studies have examined possible implications of playing piano-related posture. Most of them recognized how important the height of the chair is. When the player uses the uniform piano bench, they should make adjustments for shorter legs and low back support. Using of an adjustable piano bench seems to be the only recognizable difference between individuals.

With the recognition of the height of the chair, I found that most suggestions tend to be evaluated through the experience of performer or teachers of piano. Therefore, it is the qualitative analysis rather than quantitative.

Thomas Mark (1999) described the causes of pianist's injuries and indicated what has to happen for an injured pianist to recover. According to him, pianist's injuries are caused by: co-contraction, awkward positioning, static muscular activity, and excessive force.

Also he suggested the three principles of prevention injuries, such as sit at the correct height, avoid dropping the wrist, and avoid ulnar and radial deviation

Since it was very difficult to find quantitative research about posture of pianist, research on keyboard jobs was substituted due to the similarity in problems relating posture.

Catherine Cook and Robin Burgess-Limerick (2000) collected questionnaires regarding work patterns and musculoskeletal symptoms of 270 people for studying of computer mouse users. The 45.7% of them answered that the highest risk factors were shoulder problems. They found that relationships were between non-mouse-specific risk factors, such as stress, screen height, and shoulder elevation. Shoulder elevation was identified as a risk factor for wrist/hand and upper back symptoms.

Moffet, H. and Hagberg, M. (2002) evaluated the

*Corresponding author: dong-la@hotmail.com

impact of two laptop designs (with or without palm rest) and two work situations (on desk or lap) on neck and upper limb posture, muscle activity, and productivity. Eightsubjects performed a standardized typing task of 15 min. duration. They used a three-dimensional video system for posture of the neck, upper arm and trunk postures. A biaxial electrogoniometer was used for measuring wrist motion and for recording the muscle activity of the neck and limbs for analysis. Only minor differences in posture, wrist position, and productivity were observed when comparing the two-laptop designs in the same situation. But in desk situation, more elevation of the upper arm and higher electromyographic (EMG) levels in the trapezius and deltoid muscles and lower EMG levels in the wrist extensors.

Through review of articles, for keyboard jobs related with computers, shoulder elevation can be the problem. This is also occurring to pianists depending upon the height of the chair, especially when they are using a higher chair.

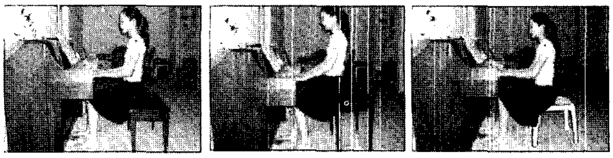
De Wilde L. and Audenaert, E (2002) studied the effect of deltoid muscles on shoulder joint function using geometrical three-dimensional ball-and-socket modeling of the shoulder joint. They concluded that elongating the muscle by changing the distance between the humeral rotation point and the deltoid insertionalong the humeral axis does not affect moment arms. However, the moments of the deltoid muscle seem more adapted to elevation in the scapular plain.

Anton, Dan and Shibley, Lee D. (2001) examined the shoulder joint moment using 2-dimensional static link segment modeling in thesagittal plane and the load of deltoid, biceps brachii and triceps brachii muscle with electromyographic(EMG) for overhead drilling positions. The findings indicated that workers performing overhead tasks should work close to their body in order to minimize shoulder forces.

2. Methodology

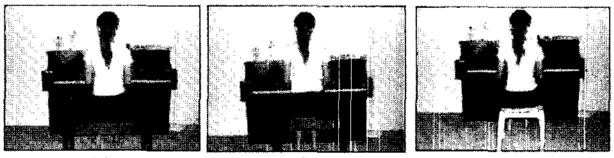
For quantitative analysis, the general procedure for analyzing the forces acting on rigid bodies in equilibrium is taken. The procedure is:

1. Find out the degrees of forearm, upper arm, and concerned muscles depending upon the height of the chairs. (Fig. 1, Fig. 2)
2. Draw a simple diagram for analyzing posture.
3. Draw the free-body diagrams of the parts constituting the system.
4. Adopt a proper coordinate system.
5. For each free-body diagram, apply the translational and rotational equilibrium conditions.
6. Calculate the force of the elbow and deltoid muscles of the shoulder depending on three chairs.



(a) (b) (c)

Fig. 1. Picture of the subject in sagittal plan.



(a) (b) (c)

Fig. 2. Picture of the subject in back plan.

The subject was an Asian female, 17 years old; she weighed 50 kg and 165 cm tall.

She has been playing the piano since age 7. For the static posture, she sat on the three chairs with playing posture. The chairs were selected for showing differences of the degrees of the arm. The dimensions of the chairs were:

1. A piano bench of 29.5 cm of width, 14 cm of length and 17cm of height.
2. A piano bench of 25 cm of width, 14 cm of length and 21.5cm of height
3. The chair of 15 cm of width, 15 of length and 15.5cm of height

The keyboard of the piano has 26.8cm from the floor, and 53 cm width from side to side. The following Table 1 shows the estimated segment length, weight and center of gravity of the subject.

Measurements of the subject and the chairs were taken with measuring tape and scale. More data was collected from tables of:

1. Body-segment Length in Proportion Stature
2. Prediction Equations to Estimated Segment Mass (in kg) From Total Body Weight W (kg)- adapted from Kroemer, Kroemer, and Kroemer-Elbert(1990) and
3. Link boundaries and locations of mass a percentage of link lengths (Dempster, 1955)
4. The proportion of deltoid, triceps and biceps was adapted from Chandler Allen Phillips (2000).

A digital camera (Nikon 885) was used to take pictures showing angles for arms and the muscles. To find out the angles, a protractor was used. (Figure 1, 2)

The deltoid muscle is used for abduction of the arm.

Table 1. The estimated length, weight and C.G of the segment

	Empirical Equation	Segment Weight of Subject
Total Arm	0.0505W + 0.01	2.54 Kg
Upper Arm	0.0274W - 0.01	WUA=1.36 Kg
Forearm	0.0189W - 0.16	WFA=0.79 Kg
Hand	0.0055W + 0.07	WH = 0.35 Kg
Deltoid	**	
Triceps	**	**
Bicept	**	**

CG of the Segment	Proportion of Segment of Subject	Segment Length of Subject	CG form Upper Link
eg=0.1237 m	*	*	*
bd = 0.1043 m	0.172 H	eh=0.2838m	43.6 %
*	0.147 H	be=0.2426m	43.0 %
*	*	*	*
*	0.08 H	ef=0.132m	*
*	0.015 H	ab=0.248m	*
*	0.015 H	ac=0.248m	*

Reduced muscle force can increase endurance and prolong the time period before the onset of fatigue for playing the piano. This study is about which posture is related with height of the chair can produce less force of the deltoid muscle. Also it is needed to calculate the force of the elbow. For this, triceps and biceps muscles are considered. The triceps muscle is used for extension of the forearm: lowering the forearm away from the upper arm, widening the elbow angle (see Figure1 (b) and Figure 2 (b)). The biceps muscle is used for flexion of forearm: raising the forearm the forearm toward the upper arm, decreasing the elbow angle (see Figure 1(c) and Figure 2 (c)).

In order to make models of posture, the three sagittal plain pictures (Figure 1) and the three back plain pictures (Figure 2) of the subject were taken. With Figure1 and Figure2, the angles for calculating forces were found and drawn as a simple diagram of the system to be analyzed (Figure 3).

For analyzing the forces acting on rigid bodies in equilibrium, the assumptions are as follows:

1. The bodies considered are to be rigid.
2 .Consider only external forces.
3. According to Newton's first law, a body is said to be in translational equilibrium if the net (or resultant) external force acting upon it is to zero. For two-dimensional motion in x-y coordinate space, this represents:
$\Sigma Fy = 0, \Sigma Fx=0$
4. The anatomical axes of rotation of joints are known.
5. The locations of muscle attachments are known.
6. The line of action of muscle tension is known
7. Segmental weights and their centers of gravity are known.
8. Frictional factors at the joints are negligible.
9. Only two-dimensional problems will be considered.
10. Angle of the deltoid muscle was assumed as 1 degree when a higher chair was used.
11. Angle of the deltoid muscle was assumed as 5 degree when a correct chair was used.
12. Angle of the deltoid muscle was assumed as 13 degree when a lower chair was used.

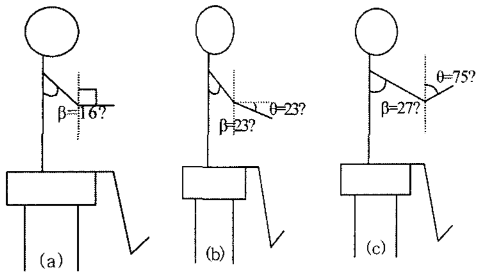


Fig. 3. Diagram of the segittal posture of depending on height of the chair.

3. Biomechanical Evaluation

The free body diagram with calculations of forces for the forearm and deltoid muscle of the system is provided. The forces of deltoid muscle depending on the height of the chair are presented in the Table 2.

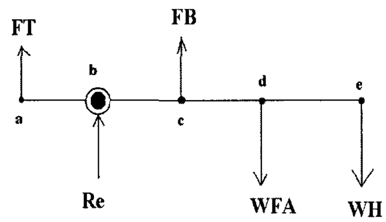


Fig. 4. Free body diagram for forearm(a)

$\theta = 90$
$\Sigma Fy = 0$
$FT + FB - Re - WFA - WH = 0$
$Re = (FT + FB) - WFA - WH$
$(FT+FB)*(ab+bc)-WFA*bd-WH*be=0$
$(FT+FB)*(0.025+0.025)-0.79*0.1043-0.35*0.2426 = 0$
$FT + FB = 4.793$
$Re=4.793 - 0.79 - 0.35 = 3.65$ (N)

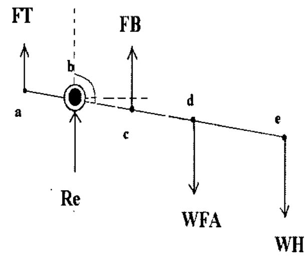


Fig. 5. Free body diagram for forearm (b)

$\theta = 113$
$\Sigma Fy = 0$
$FB - Re - WFA - WH = 0$
$Re = FB - WFA - WH$
$FB(bc*\cos 23)-WFA(bd*\cos 23)-WH(be*\cos 23)=0$
$FB = 6.69$
$Re = 6.69 - 0.79 - 0.35 = 5.55$ (N)

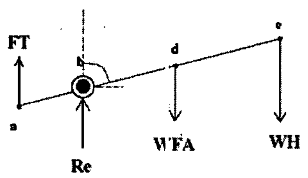


Fig. 6. Free body diagram for forearm (c)

$\theta = 75$
$\Sigma Fy = 0$
$FB - Re - WFA - WH = 0$
$Re = FB - WFA - WH$
$FB(ab*\sin 75)-WFA(bd*\sin 75)-WH(be*\sin 75)=0$
$FB = 6.68$
$Re = 6.68 - 0.79 - 0.35 = 5.54$ (N)

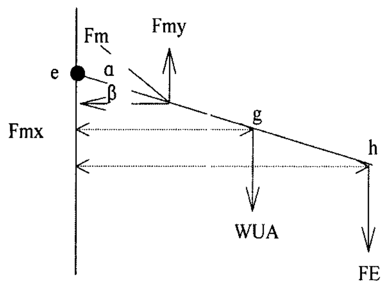


Fig. 7. Free body diagram for upper arm

$\Sigma Me = 0$
$Fmy(ef*\cos\beta)-Fmx(ef*\sin\beta)-WUA(eg*\cos\beta)-FE(eh*\cos\beta) = 0$
$FM([\sin(\alpha+\beta)](ef*\cos\beta)-Fm[\cos(\alpha+\beta)](ef*\sin\beta)-WUA(eg*\cos\beta)-FE(eh*\cos\beta)=0$

Based on the numerical analysis, the force of elbow and deltoid at shoulder depends on the height of chair.

Table 2. The force of elbow and·deltoid of shoulder

	(a)	(b)	(c)
α	5	1	13
β	16	23	27
FE	3.65	5.55	5.54
WUA	1.36	1.36	1.36
ef	0.132	0.132	0.132
eh	0.2838	0.2838	0.2838
eg	0.1237	0.1237	0.1237
Fm	105.61(N)	800(N)	51.66(N)

4. Conclusions

The force of deltoid muscle of the shoulder with static posture for playing the piano shows large differences depending on the height of the chair. On the highest chair, the force of deltoid increased with hunched shoulder. In the case of the lower seat, the force of deltoid seems to be smaller. But the force of the elbow is increased over the prefer seat. Thefindings indicate that the forearm should be leveled when the performer is sitting at the certain height of the chair erectly without hunching the shoulders.

A limitation of this study is the use of rigid 2-dimensional biomechanical analysis. Dynamic or static 3-dimensional studies may be needed to evaluate true piano playing posture. Total shoulder for the entire task of piano playing would increase in a dynamic model and may better represent the actual work. Sin the angle of the deltoid muscle, depending on height of the chair, was assumed, finding accurate angle is needed.

Further studies may also benefit from multi-planer evaluation since sagittal plane motion cannot be analyzed. Moreover it is needed to find more information about angle of the deltoid muscle.

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