Biomechanics Analysis When Delivering Baby

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***Abstract*—**Plenty of analyses based on Biomechanics were carried out on many jobs in manufactures or services. Now Biomechanics analysis is being applied on mothers who are giving birth. The analysis conducted in terms of normal condition of the birth process without Gyn Bed (Obstetric Bed). The aim of analysis is to study whether it is risky or not when choosing the position of mother's postures when delivering the baby. This investigation was applied on two positions that generally appear in common birth process. Results will show the analysis of both positions to support the birth process based on the Biomechanics analysis (Ergonomic approaches).

***Keywords*—**Biomechanics analysis, Birth process, Position of postures analysis, Ergonomic approaches.

I. Introduction

GYN bed or obstetric bed is usually used for giving birth process. This bed gives comfortable feeling and reduces the risk of back pain, leg muscle stresses and keeps assuring the open ways for baby's out. Every pregnant woman needs extra physical condition that is crucial for a smooth process of birth [1]. But, how if the patients do not have hospital facilities such as this Gyn bed during birth process?

There are so many commonly traditional positions of mothers in doing the birth process, but only two among them that are famous. Those are lying down position and half seating position. Lying down position (lithotomic) is a position where the mother lies on the obstetric bed with both of her legs straddling and hanging on the legs holder. This is a good position for the doctor to help the birth process. The baby's head is easily handed on the right direction. However, this position makes the mother difficult to push the baby out due to the gravity of the mother on the bottom and parallel with baby's position. Semi seated position is a position where the mother sits on the obstetric bed with the back supported by a pillow and both of her legs are opened. This position is more convenient and makes the baby's way out shorter and provides good oxygen supply for the fetus. However, this position makes the mother feel tired and can cause back injuries [1].

A Biomechanics analysis through Catia Program Software to both positions had been applied by Kristyanto et al. [1] which is shown that The Lying down Position is a better choice compared to half seating position regarding to the forces that impact to back bone. Those are as well as RULA and REBA analysis [1]. However, if it is concerning with the smoothing process in delivering baby than it chooses the half seating position.

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The Biomechanics analysis mentioned that based on Catia Program was produced from computational program and presented or available only in table. In this study the analysis of Biomechanics using mechanical forces applied on segment link of human body is implemented on the posture positions of mother when delivering baby (birthing process).

There are two common methods of using Biomechanics analysis based on the forces of mechanical computation. First is the Chaffin's method [2] who emphasized the forces act to segment links. The Second is Philips method [3] who had the same method as well as Chaffin but also involved the muscle as a part of the segment links components that supports the joints of human body. In this study the Phillips method is selected and is being applied in investigating the risk on the posture position of mother during birth process.

II. Method

Biomechanics is one of the aspects in ergonomics. Biomechanics applies the mechanical principals to study human movements. The proposed study of biomechanics analysis are: to produce the quantitative data of segment link of human body due to the external or internal forces, to control the stress, improving the efficiency, performance, and comfort, identifying the risk of injuries, etc. The tools of Biomechanics analysis are: Modeling, Anthropometry, Kinesiology, and Bioinstrumentation. From these tools, modeling is supposed to be the first step for simulating the problem and then making the solution.

A. Biomechanics Model

Based on Phillips [3] the model of biomechanics of human body is divided by 3 models. They are Back model, Elbow and Forehand model, and Lower Extremity and Foot model. Those models will be applied on each position of postures of mother in birthing process. As mentioned before, the two positions developed are lying down position (Fig. 1) and half sitting position (Fig. 2).

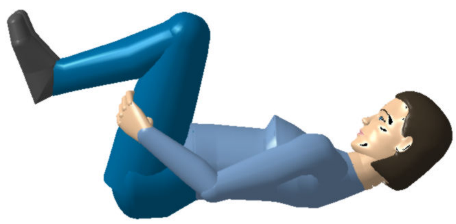

Fig. 1 Lying down position

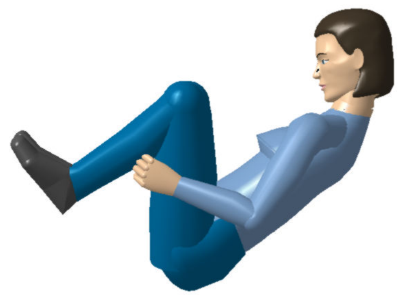

Fig. 2 Half sitting position

B. Anthropometric Data Observation

The anthropometric data from the population are needed to be collected. The data was measured from the populations which are thirty data of anthropometric pregnant woman with 25 year to 35 years old and with 23 to 39 weeks of pregnancy [1].

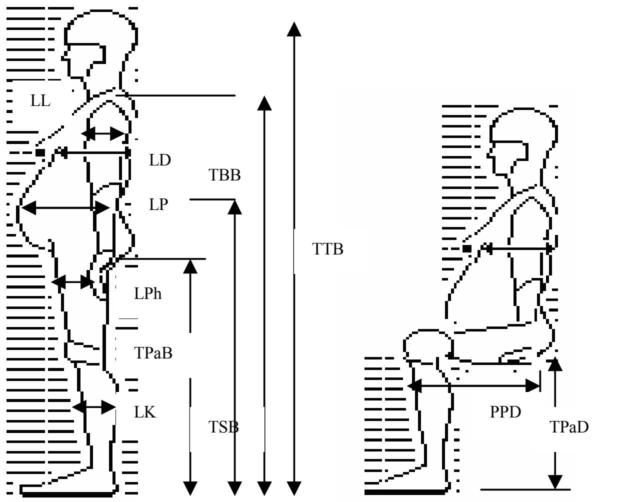

Fig. 3 Standing and sitting postures (adopted and modified from Rutter B, et. al) [4]

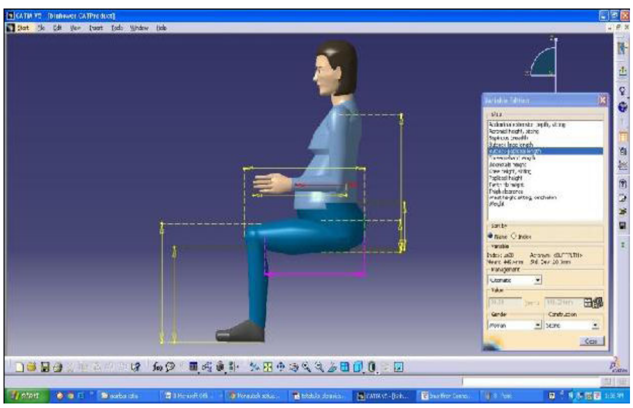

Fig. 4 Anthropometry of Pregnant Woman

The ratio of segment link to the height and the weight to human body weight are as followed the book references by Chaffin [2] and by Phillips [3]. Here it is assumed that the ratio for European people and Asian people are the same. A small research for measuring the ratio of segment links of local students of Asia (Indonesia) showed quite similar. [5].

C Kinesiology

Kinesiology will explain how the body moves, and how the segment links and joint perform movements, and also how joining muscles will support movement.

D Bioinstrumentation

The instrumentation that involves in this study instead of Anthropometer is camera. The pictures from camera are simulated using Catia program. The angles of segment links caused of movement (flexion, extension, etc) are simulated based on references plane.

III. Analysis

Based on two positions of the models, Biomechanical analyses are developed through the free body diagram of forces as follows:

A. Free Body Diagram Model of the Back (Thoracic Lumbar Spine) for Half Seating Position

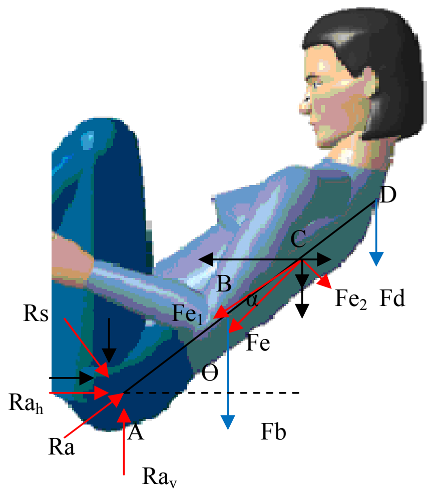

Fig. 5 Free Body Diagram Model of the back for Half Seating Position

AB = 0.15 H
AC = 0.20 H
AD = 0.30 H

H is the human height in cm

Fe is the internal force of muscle at back bone at C with angle of $\alpha = 13^\circ$

F_d is weight of upper back bone (neck and head) at D that equal 0.18 W

Ra, Rs are reaction forces, that are axis force and shear force at lumbosacral

W is the body weight times to gravity = G x g

F_b is weight of thorax and abdomen at B that equal 0.36 W

Θ is angle between segment link of back and horizontal line

CD= AD-AC=0.30H-0.20H=0.1H
$Fe = Fe_1 / \cos\alpha$
$Fe = Fe2 / \sin\alpha$
$Fe_1 = Fe_{1h} / \cos(\Theta+\alpha)$
$Fe_1 = Fe_{1v} / \sin(\Theta+\alpha)$
$Fe_2 = Fe_{2h} / \cos(90-\Theta)$
$Fe_2 = Fe_{2v} / \sin(90-\Theta)$
$Rs = Rs_v / \cos(90-\Theta)$
$Rs = Rs_h / \sin(90-\Theta)$
$Rav = Ra\sin\Theta$
$Ra = Fe_1$
$= Fe\cos\alpha$

$\sum Fy = 0$
$Ra - Rs_v - Fb - Fe_{2v} - Fe_{1v} - Fd = 0$
$Ra\ \sin\alpha - Rs\cos(90-\Theta) - 0.36W - Fe\sin\alpha\ \sin(90-\Theta) - Fe\cos\alpha\ \sin(\Theta+\alpha) - 0.18W = 0$
$Fe\ \cos\alpha\ \sin\Theta - Rs\ \cos(90-\Theta) - 0.54W - Fe\sin\alpha\ \sin(90-\Theta) - Fe\cos\alpha\sin(\Theta+\alpha) = 0$
$Rs = \{Fe\cos\alpha\sin\Theta - Fe\sin\alpha\sin(90-\Theta) - Fe\cos\alpha\sin(\Theta+\alpha) - 0.54W\} / \cos(90-\Theta)$

$\sum Fx = 0$
$Fe_{2h} - Fe_{1h} + Ra_h = 0$
$Ra_h = Fe_{1h} - Fe_{2h}$
$Ra_h = Fe\cos\alpha\cos(\Theta+\alpha) - Fe\sin\alpha\cos(90-\Theta)$

$\sum M_A = 0$
$FbAB\cos\Theta + Fe_{1v}AC\cos\Theta + Fe_{2v}AC\cos\Theta - Fe_{1h}AC\sin\Theta + Fe_{2h}AC\sin\Theta + FdAD\cos\Theta = 0$
$0.36W0.15H\cos\Theta + Fe_1\sin(\Theta+\alpha)0.20H\cos\Theta + Fe_2\sin(90-\Theta)0.20H\cos\Theta - Fe_1\cos((\Theta+\alpha)0.20H\sin\Theta + Fe_2\cos(90-\Theta)0.20H\sin\Theta + 0.18W0.30H\cos\Theta = 0$
$0.054Wh\cos\Theta + 0.20HFe\{\cos\alpha\sin(\Theta+\alpha)\cos\Theta + \sin\alpha\sin(90-\Theta)\cos\Theta - \cos\alpha\cos((\Theta+\alpha)\sin\Theta + \sin\alpha\cos(90-\Theta)\sin\Theta\} + 0.054Wh\cos\Theta = 0$
$0.020HFe = \{-0.108Wh\cos\Theta\} / \{\cos\alpha\sin(\Theta+\alpha)\cos\Theta + \sin\alpha\sin(90-\Theta)\cos\Theta - \cos\alpha\cos((\Theta+\alpha)\sin\Theta + \sin\alpha\cos(90-\Theta)\sin\Theta\}$
$Fe = \{-0.54W\cos\Theta\}/\{\cos\alpha\sin(\Theta+\alpha)\cos\Theta + \sin\alpha\sin(90-\Theta)\cos\Theta - \cos\alpha\cos((\Theta+\alpha)\sin\Theta + \sin\alpha\cos(90-\Theta)\sin\Theta\}$

If $\Theta = 30^0$ and $\alpha = 13^0$
Than

$Fe = \{-0.54W\ 0.1543\} / \{0.9074.(-0.8318)0.1543 + 0.4202(-0.3048)(-0.9880) - 0.9074\ 0.5551(-0.9880) + 0.4202(-0.9524)(-0.9880)\}$
$Fe = -0.0833W / 0.9029$
$Fe = -0.0923W$
$Rs = \{Fe\cos\alpha\sin\Theta - Fe\sin\alpha\sin(90-\Theta) - Fe\cos\alpha\sin(\Theta+\alpha) - 0.54W\} / \cos(90-\Theta)$
$= \{-0.0923W.0.9074(-0.9880) + 0.0923W.0.4202(-0.3048) + 0.0923W.0.9074\ (-0.8318) - 0.54W\} / (-0.9524)$

$Rs = -0.5387\ W / -0.9524$
$= 0.5656\ W$

$Ra = Fe\cos\alpha$
$= -0.0923W\ 0.9074$
$= -0.0838\ W$

From the calculation is shown that Fe, Rs and Ra were influenced by human body weight. Fe will impact to the back injury while Rs and Fa will impact to the delivery baby.

Free Body diagram model of the Back (thoracic lumbar spine) for Lying down Position:

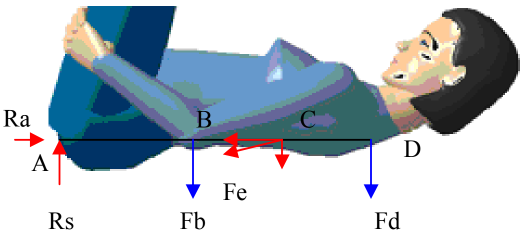

Fig. 6 Free Body Diagram Model of the back for Lying Down Position

Here α= 0 because no strain on back bone muscle happened in this position. However, only Rs, Fb, and Fd are exist.
From
$\sum Fy = 0$
$Rs - Fb - Fd = 0$
$Rs = 0.36W + 0.18W = 0.54W$

From the results showed that Rs for both position are close. In this position the reaction of internal force do not help or support the baby push away.

B. Free Body Diagram Model of the Elbow and Forearm for Half Seating Position

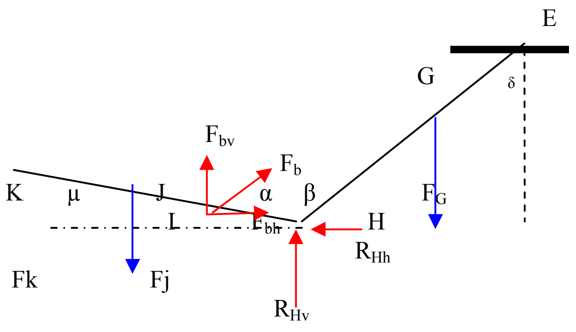

Fig. 7 Free Body Diagram Model of the Elbow and Forearm for Half Seating Position

EH = 0.20H
EG = 0.10H
HK= 0.20H
HI = 0.015H
HJ = 0.01H
F_b = Internal force of bicep muscle
F_G = Weight of upper arm = 0.03W

F_J = Weight of forearm and hand = 0.02W
R_E is the reaction of elbow
β = the angle of forearm or forehand to vertical line
δ = the angle of upper arm to vertical line
μ = the angle of forearm or forehand to horizontal line
α = the angle of internal force or bicep to forearm or forehand = 13^0

$\sum Fy = 0$
$R_{Hv} - F_G + F_{bv} - F_J = 0$
$R_{Hv} = F_G - F_{bv} + F_J$
$= F_G + F_J - F_{bv}$
$= 0.03W + 0.02W - F_{bv}$
$= 0.05W - F_{bv}$

$\sum Fx = 0$
$-R_{Hh} + F_{bh} = 0$
$R_{Hh} = F_{bh}$

$\sum M_H = 0$
$Fg\ GHcos\alpha + Fbv\ HIcos(90-\beta) + Fbh\ HIsin(90-\beta) - Fj\ HJcos(90-\beta) = 0$
$0.03W.0.1Hcos\alpha + 0.015H\ Fbv\ cos(90-\beta) + 0.015H\ Fbh\ sin(90-\beta) - 0.02W\ 0.01H\ cos(90-\beta) = 0$
$0.03W.0.1Hcos\alpha + 0.015H\ Fb\ sin\alpha\ cos(90-\beta) + 0.015H\ Fb\ cos\alpha\ sin(90-\beta) - 0.02W\ 0.01H\ cos(90-\beta) = 0$
$0.003W\ Hcos\alpha + 0.015H\ Fbsin\alpha\ cos(90-\beta) - 0.015H\ Fbcos\alpha\ sin(90-\beta) - 0.0002W\ H\ cos(90-\beta) = 0$
$Fb = \{0.0002WHcos(90-\beta) - 0.003WHcos\alpha\} / \{0.015Hsin\alpha cos(90-\beta) + 0.015Hcos\alpha\ sin(90-\beta)\}$

$Fb = \{0.0002Wcos(90-\beta) - 0.003Wcos\alpha\} / \{0.015sin\alpha cos(90-\beta) + 0.015cos\alpha\ sin(90-\beta)\}$
$Fb = \{0.0002Wcos(90-\beta) - 0.003Wcos13^0\} / \{0.015sin13^0cos(90-\beta) + 0.015cos13^0\ sin(90-\beta)\}$
$= \{0.0002Wcos(90-60) - 0.003Wcos13^0\} / \{0.015sin13^0cos(90-60) + 0.015cos13^0\ sin(90-60)\}$
$= \{0.0002Wcos30^0 - 0.003Wcos13^0\} / \{0.015sin13^0cos30^0 + 0.015cos13^0\ sin30^0\}$
$Fb = -0.00269W / -0.01248$
$= 0.2155\ W$

$R_{Hv=} 0.05W - F_{bv}$
$= 0.05W - Fbsin13^0$
$= 0.05W - 0.2155W.\ 0.4202$
$= 0.05W - 0.09056W$
$= -\ 0.04056\ W$

$R_{Hh} = F_{bh}$
$= Fb\ cos13^0$
$= 0.2155W.0.9075$
$= 0.1956\ W$

From the result shown that the internal force at bicep muscles also depend on the human body mass or weight.

Free Body diagram model of the Elbow and Forearm for Lying Down Position has same model to Half Seating Position.

C. Free Body Diagram Model of Lower Extremity and Foot for Half Seating Position

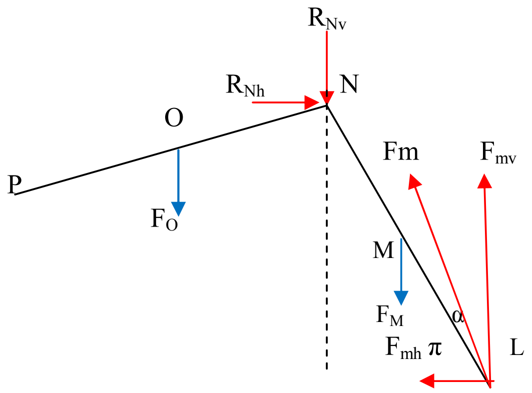

Fig. 8 Free Body diagram model of Lower Extremity and Foot for Half Seating Position

LN = Upper leg = 0.24H
NP = Foot and foreleg =0.29H
LM= 0.12H
NO= 0.03H
R_{Nv} is vertical reaction on Knee
R_{Nh} is horizontal reaction on Knee
F_M is weight of upper leg = 0.10W
F_O is weight of foot and foreleg = 0.15W
F_m is internal Force of leg muscle
π = the angle of leg and horizontal line.
α = the angle of internal force to the leg

$\sum Fy = 0$
$F_{mv} + R_{Nv} - F_M - Fo = 0$
$R_{Nv} = Fo + F_M - F_{mv}$

$\sum Fx = 0$
$F_{mh} - R_{Nh} = 0$
$R_{Nh} = F_{mh}$

$\sum M_N = 0$
$F_M\ MNcos(90-\pi) - F_{mv}\ LNcos(90-\pi) + F_{mh}\ LNsin(90-\pi) - Fo\ NOcos(90-\pi) = 0$
$0.1W\ 0.12Hcos(90-\pi) - F_{mv}\ 0.24Hcos(90-\pi) + F_{mh}\ 0.24Hsin(90-\pi) - 0.15W\ 0.03Hcos(90-\pi) = 0$
$0.1W\ 0.12Hcos(90-\pi) - F_m sin(\alpha+\pi)\ 0.24Hcos(90-\pi) + F_m cos(\alpha+\pi)\ 0.24Hsin(90-\pi) - 0.15W\ 0.03Hcos(90-\pi) = 0$
$Fm = \{0.012WHcos(90-\pi) - 0.0045WHcos(90-\pi)\} / \{0.24Hcos(\alpha+\pi)sin(90-\pi) - 0.24Hsin(\alpha+\pi)\ cos(90-\pi)\}$
$Fm = \{0.012Wcos(90-\pi) - 0.0045Wcos(90-\pi)\} / \{0.24cos(\alpha+\pi)sin(90-\pi) - 0.24sin(\alpha+\pi)cos(90-\pi)\}$
$Fm = \{0.0075Wcos(90-\pi)\} / \{0.24cos(\alpha+\pi)sin(90-\pi) - 0.24sin(\alpha+\pi)cos(90-\pi)\}$

If $\pi = 70^0$ and $\alpha = 13^0$

$Fm = 0.00306W / \{0.05467 - 0.09484\} = 0.00306W / -0.04017$

$Fm= - 0.0762W$

$R_{Nv} = Fo + F_M - F_{mv}$
$= 0.15W + 0.10W – Fm \sin(\alpha+\pi)$
$= 0.25W + 0.0762W\ 0.96836$
$= 0.3238W$
$R_{Nh} = F_{mh}$
$= Fm \cos(\alpha+\pi)$
$= -0.0762W\ 0.2495$
$= - 0.0190W$

F_m with on the opposite direction showed that muscle of upper leg had compression stresses and R_{Nv} and R_{Nh} will impact to the fatigue of leg because of the leg masses.

For the Lying down position the same model and calculation are applied. The probably different is only on the angle of π. On this position the π may less than 70^0.

IV. Discussion

As it was mentioned before that based on medical advices from a midwife, the best position for delivering baby is Half seating position. This position will make the mother do the birthing process easily. This position gives the possibility to pull and lift up the leg closer to the chest or abdomen. By this position as keeping both leg open and a bit contraction will help the head of the baby to come out and the process will become easier. The suggested position can be seen in the figure below.

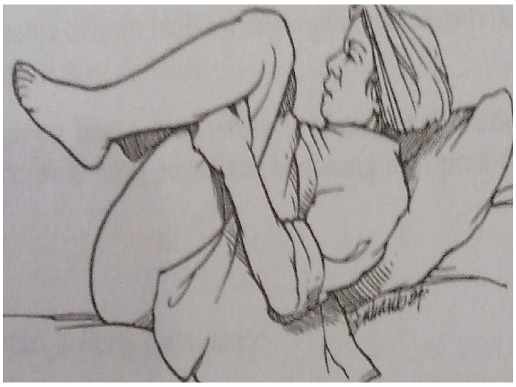

Fig. 9 The position that most midwife suggested (as book references for midwife)

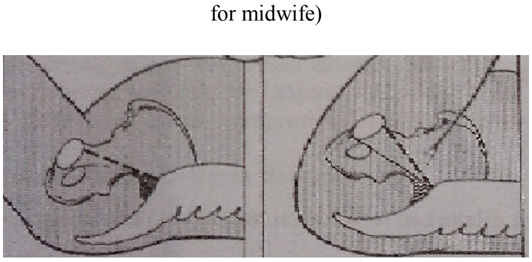

Fig. 10 Pulling the leg into the chest direction gives easy way to baby

The Half Seating position of posture may the center of mass does not located on lower position and parallel with baby position and then problem that squeezed large vessels under baby location is reducing. The benefit of half seating position is the centre of baby's line is shorter and supply of oxygen from mother to fetus is smooth and maximum. All those perspectives come from medical view or site. From Biomechanics analysis it was suggested that better position of posture when delivering baby is the position of posture that do not have injury risky and it is Lying Down Position. This is showed by Fm= 0. The human body mass or weight also contributes to the problem on each position. The sense of fatigue of forehand muscle and leg muscle during birthing process are also needed consideration. Especially for keeping both legs open and pull it closing to the chest or abdomen.

The same results with different analysis using CATIA programming software on to two scenarios position were compared (as shown in [1]). The better result is also on the Lying down position. Based on the biomechanics analysis menu using Catia software, only on part of the Body Load Compression the value of Lying down Position is greater than Half Sitting Position. This load impacts to the baby and makes the mother need extra straining to push out the baby.

V. Conclusion

Biomechanics analysis can be applied in many processes of jobs including the birthing process. The analysis will help to reduce the back injury risk and also the fatigues of other part of the human body anatomy during the birth process.

From the analysis showed that if it is respect to ergonomic analysis through biomechanical calculation the Lying down position is the choice. But if the respect is oriented to medical advices the Half Seating position is the choice. To solve the problem it is required to follow the Half Seating Position but should be completed by tools which can help to reduce the back pain or injury and the fatigue feeling of forehand and foreleg. The Gyn bed (obstetrics bed) is the tool or equipment that can solve these problems. If the patient lives too far from the hospital facilities, than she will difficult to overcome this problem.

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