RESPONSE OF A PREGNANT UTERUS TO IMPACT LOADING

Karel Jelen, Stanislav Otàhal, Antonín Doleal,
Univerzita Karlova v Praze, Praha, Czech Republic

INTRODUCTION: Gravidity is a natural physical state of women that normally lasts 40 weeks. For this reason all physical activities of women in this period are appropriately modified.

On one hand, the physical activities endangering the pregnancy are reduced during gestation. On the other hand, however, it is advisable to maintain or adapt such physical activities that may lead either to psychic health improvement and maintenance, or to convalescence after a possible trauma, or preparation for the childbirth.

The functional ability of the human power system changes continually during the lifetime. The ability of a quality movement generation and the effeciency are increased or reduced, and due to the fatigue or an injury the power system may even be mechanically destroyed.

Therefore it is necessary to get inside into a mechanical structure of this system's behavior, and solve the system's exertion in order to avoid or reduce consequences of the organism's interactions with the environment.

Mathematical modeling may replace or approximately approach the process of the real exertion of the power system of an individual that, for many practical reasons, cannot be applied *in vivo* (extreme weight load and vibrations, car accidents, experiment expenditures, experiments on gravid women, etc.).

Trauma is one of the very frequent interactions of an individual with the environment. Czech authors dealing with trauma in the area of biomechanics are e.g. JELEN (1991), KARAS (1996), TURKOVA (1997) and others.

Injuries in general, and especially injuries of pregnant women are an important theme in a society - e.g. car injuries representing two-thirds of all traumas during gestation are linked with a high mortality of the fetus, e.g. *abruptio placentaes*.

Trauma as a cause of gravidity complications represents 6-7% of all complications in the USA, and even more in Europe. FARMER (1990), HOFF (1991), MURDOCH (1991) and others. A special solution of pregnant women's trauma consequences due to car accidents is a worldwide problem of a great importance. ALI (1997), PEARLMAN (1996, 1997), SCHNEIDER (1993), TURKOVA (1997), WALLACE (1997) and others.

Regarding the general problem of hydroviscous and elastic vibrations of the systems, solving the vibrations range during gravidity is necessary - in common locomotion, work and sport activities, or trauma.

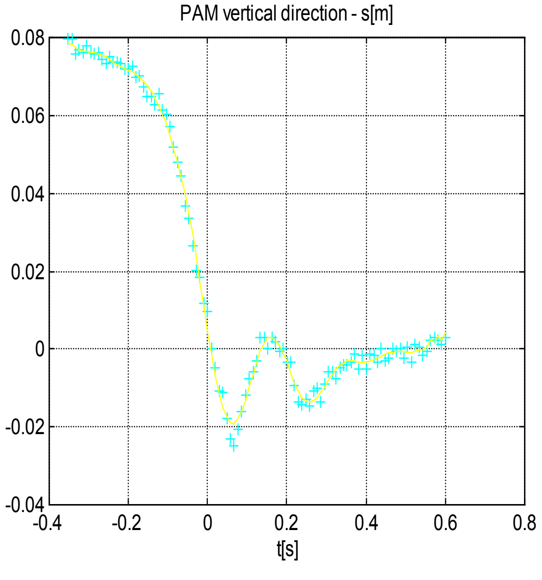
Model simulation and experimental studies dealing theoretically and practically with vibrations, rigidity and power effects of the interactions on the human power system focused on gravid women, are necessary for solving the presented problem. Using a sufficient data volume analysis and the latest computer engineering methods relating to such complex systems, a rational solution of the pragmatic prevention tasks can be expected as the result of the knowledge synthesis.

METHODS AND PROCEDURES OF DATA COLLECTION: The speed cinematographic recording method of the frequency of 103 turns/s. was used for the characteristics calculation of a strongly absorptive, aperiodic, over-critical vibration of the abdomen and topically relevant organs of a pregnant woman. A pregnant woman was standing quietly on tiptoe and then fell on her heels. The fall drop on tight lower extremities was 8 cm.The solution was supplied with a point trajectory. For further simplification the point was considered as a mass point, to which the weight of all movable abdomen parts is related. The actuating impuls with a short time duration (with a possibility to neglect the shape of the impuls curve) was 6.4 Ns as a teoretical maximum. The weight (*m*) of the vibrating abdomen (a gravid uterus with topically relevant organs) was 5.1 kg.

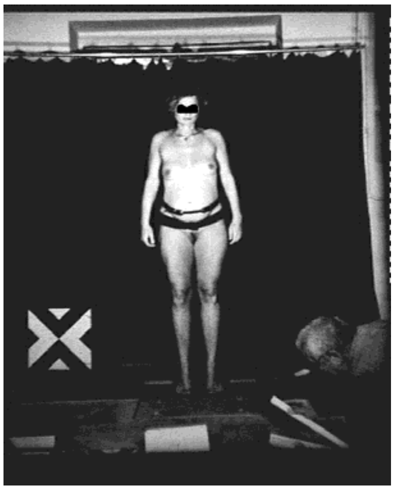
The model was considered as a mass point system located by means of a spring and a shock-absorber in all three directions of the system of coordinates. The dynamic characteristics solution was provided for the perpendicular direction, and consequently the absorptive characteristics were displayed. Except for the vibrating abdomen weight *m* = 5.1 kg, two absorptive characteristics were the only input data. The discrete points of the y-coordinate were approximated by a polynomial approximation. After appropriate values deduction from the adequately set up graphs, particular frequencies, rigidity and proportional absorption were calculated.

Graphic interpretation of vertical direction analytically deducted from the high-frequency cinematographic recording of the response of a gravid uterus and topically relevant organs on impact loading.

Impact loading course



Experimental situation



RESULTS: The experimentally discovered frequency and other selected characteristics of a behavior of an examined object are as follows:

Impulse	2,72 Ns				
frequency f_0	**1,07**	1,87	2,91	4,78	8,75 Hz
period	**0,93**	0,53	0,34	0,20	0,11 s
absorption Ω_0	**6,73**	11,75	18,34	30,0	54,9 s^{-1}
amplitude a	9,22	5,30	3,84	2,95	2,07 mm

Math model results for critical absorption $\Omega_0 = \Omega_b$

frequency f_0	0,31	0,55	0,79	**1,07** Hz
period T	3,14	1,79	1,26	**0,93** s
absorption Ω_b	2,0	3,5	5,0	**6,7** s^{-1}
amplitude y_{min}	- 86,0	-49,0	- 34,0	- 25,0 mm
amplitude y_{max}	4,0	1,0	1,0	1,0 mm

The **BOLD numbers** means the best results of experiment and math model parameters.

DISCUSSION: These measurements and the model interpretation in our case imply that the real head frequency of a pregnant uterus (32nd week) and topically relevant organs in the frontal plane of the vibration is cca 1-2 Hz. It implies a high sensitivity to the resonance just for this frequency. The resonance range can be considered one of the ranges of an increased risk for the foetus. This real frequency reflects other quantities - rigidity *k* and the uterus´ weight with the foetus *m*. It shows that the suspension rigidity of the uterus and the weight *m* (real frequency) will be significantly changed with a higher gravidity degree. The resonance frequency may be expected to reflect the pregnancy pathology, foetopathy and multiple pregnancy.

CONCLUSION: With respect to the methodological difficulty of gaining the data and a pilot character of the project, the presented characteristics must be taken as limiting. At first the results will be verified by means of dynamic recording of the object, and then made more accurate. Followingly they will be used in mathematical modeling of the gravid uterus´ impact loading ("insert pregnant") - PEARLMAN (1996). Further saturation of the model with a greater number of flexibility and rigidity parametres of the appropriate ligaments, muscles and uterus deducted from the technical examinations of the tissues is pressumed.
Through these steps, the required verification instruments of calculated and measured values of the impact loaded gravid woman will be developed. They will also contribute to a solving of the construction of e.g. passive security elements in the means of transportation, establishment of protective physical activity regimens, aids and systems in overloading of the human organism in essential stress situations in the gravid women´s interaction with the environment - especially in the area of trauma due to car accidents of gravid women.

REFERENCES:
Ali, J., Yeo, A., Gana T. J., McLellan, B. A. (1997). Predictors of Fetal Mortality in Pregnant Trauma Patients. *J. Trauma.* **42**(5), 782-785.
Bermond, F., Cesari, D., Alonzo, F., Matyjewski, M. (1992). Mathematical Simulaton of the Pedestrian Leg in Lateral Impact. In *Proceedings of the 1992*

International IRCOBI Conference on the Biomechanics of Impacts, Verona, Italy, September 9-11 (pp 61-72).
Farmer, D. L., Adzick, N. S. et al. (1990). Fetal Trauma: Relation to Maternal Injury. *J. Pediatr. Surg*. **25**(7), 711-714.
Hoff, W. S., D'Amelio, L. F. et al. (1991). Maternal Predictors of Fetal Demise in Trauma during Pregnancy. *Surg. Gynecol.Obstet*. **172**(3), 175-180.
Jelen, K. (1991). Biomechanical Estimate of Output Force of Ligamentum Patellae in Case of its Rupture during Jerk. *AUCG* **27**(2), 71–82.
Hirokawa, S. (1991). Three-Dimensional Mathematical Model Analysis of the Patellofemoral Joint. *Biomechanics* 24(8), 659-671.
Karas, V. (1996). Tolerance Organismu. In *6. konference Biomechanika* Slovaka (pp.97-100).
Murdoch, D. G., Ahmed, Y., Dubowitz, L. M. (1991). Maternal Trauma and Cerebral Lesions in Preterm Infants. *Br. J. Obstet. Gynaecol*. **98**(12), 292-294.
Pearlman, M. D. (1996). Automobile Crash Simulation with the First Pregnant Crash Test Dummy. *Am. J. Obstet. Gynecol*. **175**(4/1), 977-981.
Pearlman, M. D. (1997). Motor Vehicle Crashes, Pregnancy Loss and Preterm Labor. *International Journal of Gynecology and Obstetrics* **57**, 127-132.
Schneider, H. (1993). Trauma und Schwangerschaft. *Arch. Gynecol. Obstet*. **253** Suppl., 4-14.
Turkova, Z., Kovanda, J. (1997). „Seat Belt" Syndrom v thotenství. *eská gynekologie* **62**(5), 285-287.
Valenta, J. et al. (1993). Biomechanics (Clinical Aspects of Biomedicine, 2) (pp. 397-497). Amsterdam: ELSEVIER.
Wylie, C. R. (1966). Advanced Engeneering Mathematics. 3rd ed. New York: Mc. Graw Hill Book Comp.
Yang, J., Kajzer, J. (1992). Computer Simulation of Impact Response of the Human Knee Joint in Carpedestrian Accidents. In *Proceedings of the thirty-sixth Stapp Car Crash Conference*, Seattle, Washington, November 2-4 (pp. 203-217).
Wallace, C. (1997). General Practitioners' Knowledge of and Attitudes to the Use of Seat Bealts in Pregnancy. *Ir. Med. J*. **90**(2), 63-64.