REDUCING OF STRESS IN THE HIP JOINT ARTICULAR SURFACE IN SKIING

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INTRODUCTION

It was shown that too high contact stress in the articular surface of the hip joint can accelerate the arthrosis development in the hip joint (Hadley, 1990). Increased contact stress in the hip joint articular surface can result from too small hip joint articular surface and/or from too high resultant hip joint force. Since the resultant hip joint force is on the average increased during sport activities it is understandable that the incidence of the hip arthrosis among people with high exposure to sport is significantly higher compared to those with low exposure (Vingard, 1993). The acetabular dysplasia in sportsmen, i.e. small femoral head coverage, additionally increases the probability of hip arthrosis development. During skiing changes in the position of the upper body occur. They are associated with varying degrees of pelvic tilting, which influence the hip joint contact stress distribution. The aim of this work is to determine how acetabular dysplasia and pelvic tilt affect the hip joint contact stress distribution after shifting of the upper part of the body towards the weight-bearing leg in slow skiing.

METHODS

A three-dimensional model of the hip joint articular surface is used in order to calculate hip joint contact stress distribution (Iglič, 1993). In this model the femoral head is represented by a sphere, while the acetabulum is represented by a fraction of spherical shell. The radius of the hip joint articular surface sphere (r) is taken to be the mean of the radii of the femoral head sphere and the acetabular shell. The stress integrated over the entire weight bearing area yields the resultant hip joint force **R** (Iglič, 1993).

While calculating R (Iglič, 1990), different positions of the body in the one legged stance is simulated by different values of the lever arm (a) of the force ($\mathbf{W}_B$ - $\mathbf{W}_L$), where $\mathbf{W}_B$ is the body weight and $\mathbf{W}_L$ is the weight of the leg. In the reference body position in the one-legged stance (Fig.1A), the value of the lever arm ($a = a_n$), which lies in the frontal plane of the body, is calculated according to the approximative expression (Iglič, 1990). In the inclined body position in the one-legged stance, where the center of body mass is displaced toward the supporting leg (Fig.1B), the lever arm of the force ($\mathbf{W}_B$ - $\mathbf{W}_L$) is reduced ($a < a_n$).

In the reference body position in the one legged stance (Fig.1A), the inclination of the pelvis towards the horizontal plane (described in this work by the angle φ) is approximately zero. On the other hand, in the inclined body position in the one legged stance (Fig.1B), where the trunk is inclined

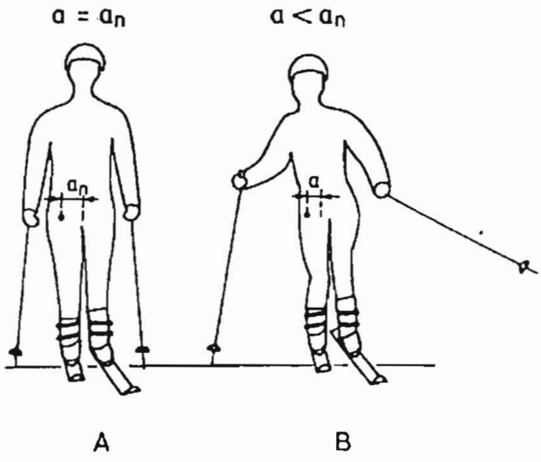

Figure 1. Schematic presentation of two different characteristic body positions in the one-legged stance: reference ($a = a_n$) and inclined ($a < a_n$), where the center of body mass is displaced towards the hip joint center of the supporting leg.

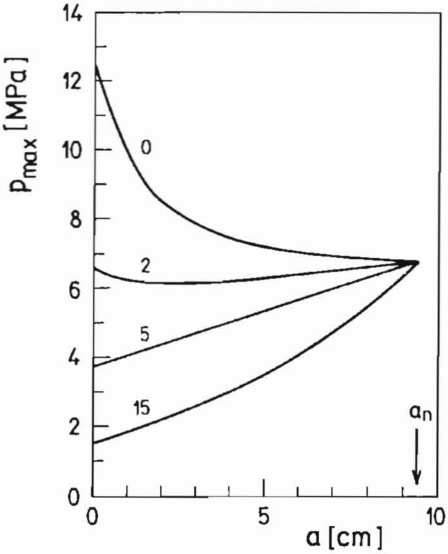

Figure 2. The maximal value of the stress in the human hip joint articular surface p_{max} as a function of the lever arm a of the force ($\mathbf{W}_B$ - $\mathbf{W}_L$) for $\vartheta_{CE,o} = 2^o$ and four values of φ_o : 0^o, 2^o, 5^o, and 15^o. The values of the model parameters used are : $W_B = 800$ N, $r = 2.7$ cm.

towards the supporting leg, the pelvis is inclined relative to the horizontal plane. As a consequence, the lateral coverage of the femoral head, i.e. the centre-edge angle (ϑ_{CE}) is increased : $\vartheta_{CE} = \vartheta_{CE,o} + \varphi$, where $\vartheta_{CE,o}$ is the

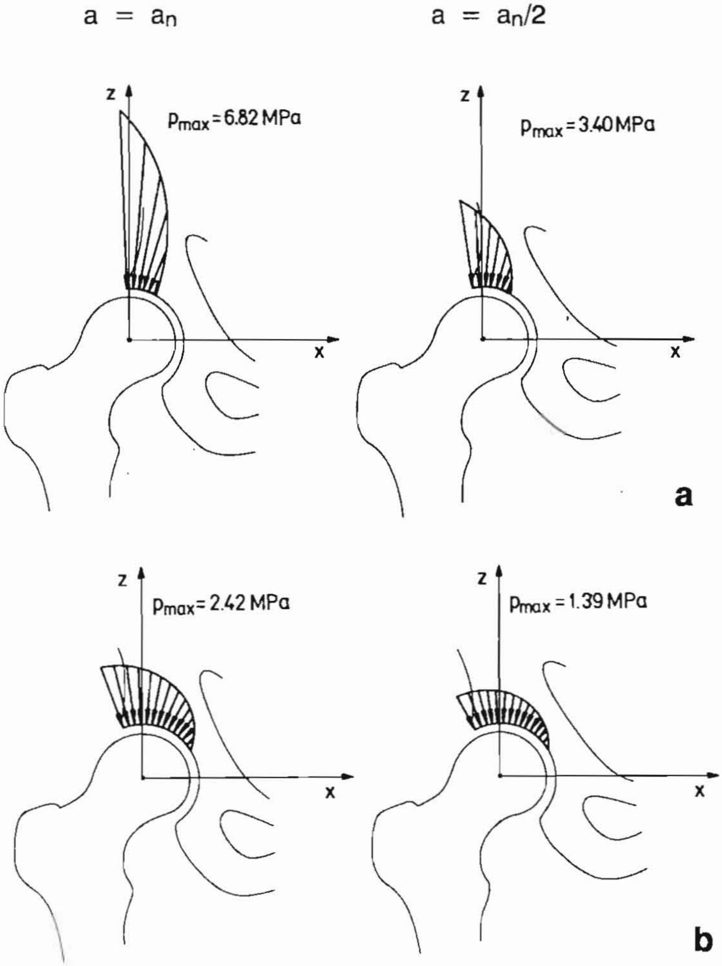

Figure 3. The calculated distribution of stress in the human hip joint articular surface in reference ($a = a_n = 9.4$ cm) and inclined ($a = a_n/2$) position of the upper part of the body in the one legged stance for $\varphi_o = 15^o$ and two reference values of Wiberg angle ϑ_{CE} : $\vartheta_{CE,o} = 2^o$ (a), and $\vartheta_{CE,o} = 20^o$ (b). The values of W_B and r are the same as in the previous figure.

value of ϑ_{CE} in the reference body position (Fig.1A) where $\varphi = 0$. The inclination φ is related to the lever arm a. Due to simplicity we use in this work the following approximative relation : $\varphi = \varphi_o \ (1 - a/a_n)$, where φ_o is the value of φ at $a = 0$.

RESULTS

It is shown in Fig.2 that the decrease of the hip joint contact stress after shifting of the upper part of the body towards the supporting leg is more effective in the case of large inclination of the pelvis during the shifting of the upper part of the body towards the supporting leg. It is also shown that after shifting of the upper part of the body towards the supporting leg stress can be in the case of pronounced acetabular dysplasia and small inclination of the pelvis even increased in spite of the fact that the resultant hip joint force is considerably reduced. The reason for such surprising result is that at large displacement of the trunk toward the the supporting leg the resultant hip joint force **R** becomes nearly vertical and consequently in case of dysplastic hips with small centre-edge angles stress in the hip joint articular surface is extremely high in the vicinity of the acetabular edge (Fig.3a).

CONCLUSION

In accordance with the results of this study it can be concluded that the subjects with pronounced acetabular dysplasia should be encouraged to turn during skiing with increased pelvic tilt on the side of the non-weight-bearing leg with simultaneously shifting of the upper part of the body towards the weight-bearing leg. In this way the dysplastic hip is unloaded to an optimum degree. Consequently, the risk for arthrosis development is decreased.

REFERENCES

1. Hadley, N.A., Brown, T.D., Weinstein, S.L. (1990). The effects of contact pressure elevations and aseptic necrosis on the long-term clinical outcome of congenital hip dislocation. J. Orthop Res., 8, 504-513.

2. Iglič, A., Srakar, F., Antolič, V., Kralj-Iglič, V., Batagelj, V. (1990). Mathematical analysis of Chiari osteotomy. Acta. Orthop. Iugosl., 20, 35-39.

3. Iglič, A., Kralj-Iglič, V., Antolič, V., Srakar, F., Stanič, U. (1993). Effect of the periacetabular osteotomy on the stress on the human hip joint articular surface. IEEE Trans. Rehab. Engr., 1, 207-212.

4. Vingard, E., Alfredsson, L., Goldie, I., Hoghstedt, C. (1993). Sports and osteoarthrosis of the hip : an epidemiologic study. Am. J. Sports Med., 21, 195-200.