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PŮVODNÍ PRÁCE

Reducing the Stress in the Articular Surface of the Hip Joint after Shifting the Upper Part of the Body towards the Painful Hip

Snížení napětí na kloubních plochách kyčelního kloubu při pohybu horní části těla směrem k bolestivé kyčli

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SUMMARY

In this work the change of stress distribution in the hip joint articular surface after shifting of the upper part of the body towards the painful hip due to pain reflex is estimated theoretically by using a three dimensional mathematical model. It is shown that after displacement of the upper part of the body towards the painful hip the stress in the hip joint can be in case of poor femoral head coverage and small inclination of the pelvis very little decreased in spite of the fact that the resultant hip joint force is reduced considerably.

Key words: stress in the hip joint, body shitting.

SOUHRN

V předložené práci autoři určují změny v rozložení napětí na kloubním povrchu kyčelního kloubu při pohybu horní části těla směrem k bolestivé kyčli v důsledku bolestivého reflexu – a to teoreticky použitím trojrozměrného matematického modelu. Ukazují, že po pohybu horní části těla směrem k bolestivé kyčli napětí v kyčelním kloubu může v případě vadného krytí hlavice stehenní kosti a malého úhlu pánve být jen o málo menší, přestože výsledná síla v kyčelním kloubu je podstatně snížena.

Klíčová slova: napětí v kyčelním kloubu, náklon trupu.

INTRODUCTION

Shifting of the upper part of the body towards the painful hip due to pain reflex causes a displacement of the center of gravity and of the muscle attachment points. Consequently, the magnitude and direction of the resultant hip joint force and the corresponding stress distribution in the hip joint articular surface are changed (5, 6, 8). The aim fo this work is to estimate theoretically the change of stress distribution in the hip joint articular surface after shifting the upper part of the body toward the painful hip due to pain reflex.

METHODS

A three dimensional model of the hip joint articular surface (Fig. 1) is used in order to calculate stress distribution in the hip joint articular surface after shifting of the upper part of the body towards the supporting limb. The model is presented in detail elsewhere (5), therefore only a brief review of the model is given here. In this model the femoral head is represented by a sphere, while the acetabulum is represented by a fraction of a 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. It is assumed that the stress at a particular point in the hip joint articular surface (p) is approximately proportional to the cosine of the angle between this point and the pole of the stress distribution (1). The stress integrated over the antire weight bearing area yields the resultant hip joint force R.

The resultant hip joint force various body positions is calculated separately by using a static three dimensional model of an adult hip in one legged stance (2, 3, 4). While calculating R, different positions of the body in the one legged stance are simulated by different values of the lever arm (a) of the force ($W_B - W_L$), where W_B is the body weight and W_L is the weight of the free leg (2).

In the normal body position in the one-legged stance (Fig. 2A), the value of the lever arm a, which lies in the frontal plane of the body, is calculated according to the approximative expression of McLeisch and Charnley (7): $a_n = 9.4$ cm (2). In the inclined body position of the one-legged stance, where the center of body mass is displaced toward the supporting leg (Fig. 2B), the lever arm of the force ($W_B - W_L$) is reduced

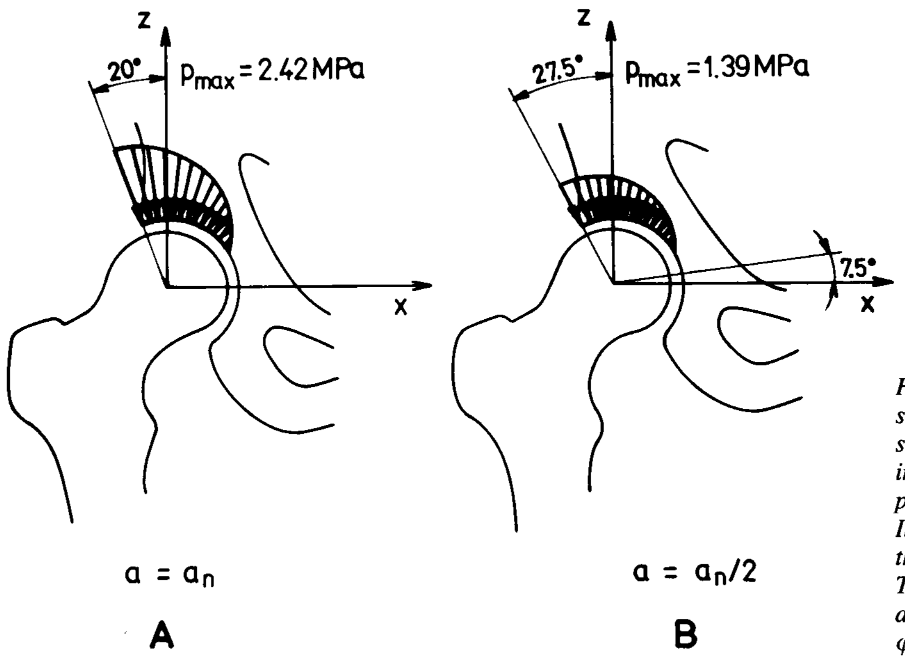

Fig. 1. The calculated distribution of stress in the human hip joint articular surface in the normal ($a = a_n$) and inclined ($a = a_n/2$) position of the upper part of the body in the one legged stance. In the normal body position we take for the value of Wiberg angle $\upsilon_{CE,o} = 20°$. The values of the model parameters used are: $W_B = 800\,N$, $r = 2.7\,cm$ and $\varphi_o = 15°$. The calculated value of υ_{CE} in the inclined body position is 27.5°

($a \leqq a_n$). Consequently the resultant hip joint force R is reduced too (2).

In the normal body position of 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 of the one legged stance, where the trunk is inclined towards the supporting painful limb, the pelvis is inclined relative to the horizontal plane (Fig. 1B). As a consequence, the lateral coverage of the femoral head, i.e. the centre-edge (CE) angle of Wiberg (υ_{CE}) (9) is increased:

$$\upsilon_{CE} = \upsilon_{CE,o} + \varphi\,, \quad (1)$$

where $\upsilon_{CE,o}$ is the value of υ_{CE} in the normal body position (Fig. 1A) where $\varphi \cong 0$. The inclination φ is related to the lever arm of the force ($W_B - W_L$). Due to simplicity we use in this work the following approximative linear relation:

$$\varphi = \varphi_o(1 - a/a_n)\,, \quad (2)$$

where φ_o is the value of φ at a = 0.

RESULTS AND DISCUSSION

Figure 2 shows the calculated distribution of stress in the human hip joint articular surface in the normal and in the inclined position of the upper part of the body for the CE Wiberg angle 20°. The symbol p_{max} denotes the maximal stress in the hip joint articular surface. As we can see in Figure 2 the stress in the hip joint articular surface is significantly decreased after shifting of the upper part of the body towards the supporting leg. It was calculated that for normal values of Wiberg angles $\upsilon_{CE,o}$ this is true for all values of parameter φ_o, which determines the extent of inclination of the pelvis after shifting of the upper part of the body. However, it can be seen in Figure 3 that in the case of poor femoral head coverage (very small Wiberg angles $\upsilon_{CE,o}$) after large displacement of the upper part of the body towards the supporting leg (small values of a) the maximal stress in the hip joint can be for small inclination of the pelvis (small φ_o) very little decreased in spite of the fact that the resultant hip joint force is reduced considerably. In the case of $\varphi_o \leqq 2°$ the value of p_{max} is even increased after large displacement of the

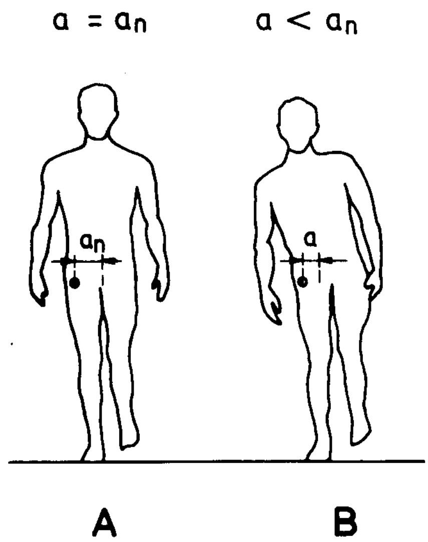

Fig. 2. Schematic presentation of two different characteristic body positions in the one-legged stance: normal ($a = a_n$) and inclined ($a < a_n$), where the center of body mass is displaced towards the hip joint center of the supporting leg

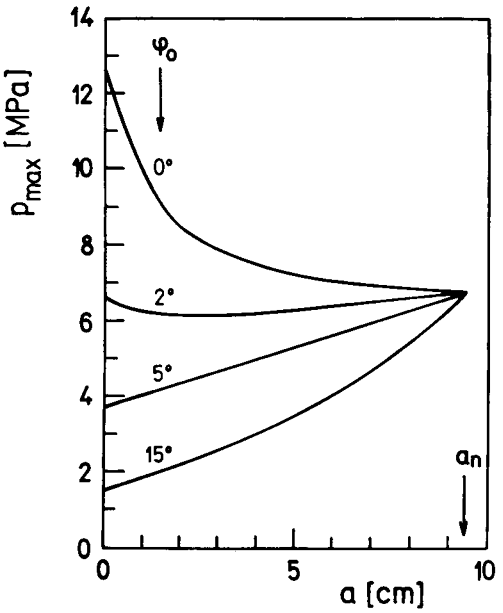

Fig. 3. The maximal value of the stress in the human hip joint articular surface p_{max} as a function of the lever arm a of the force ($W_B - W_L$) for $\upsilon_{CE,o} = 2°$ and four values of φ_o: 0°, 2°, 5°, and 15°. The values of W_B and r are the same as in the previous figure

upper part of the body. The reason for such a surprising result is that at large displacement of the trunk toward the painful hip, the direction of the resultant hip joint force R becomes nearly vertical. Consequently in the case of a dysplastic hip with small Wiberg angle $\upsilon_{CE,o}$ the stress in the hip joint articular surface is extremely high in the vicinity of the acetabular edge.

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