Introduction

Locomotor movements present an unusually stable and typical structure. Its beginning and mastering in children are very intriguing processes and the whole inventory of its biomechanical patterns changes with age. BERNSTEIN (1967) investigated the walking and running of children and made important considerations regarding its biomechanical features. Net joint moments can be considered as causes of the movements and they represent the net kinetic effect of all muscles and ligaments that cross a given joint and of other frictional forces. The study of net joint moments during locomotion in children can contribute to a better understanding of the coordination processes and loading characteristics of the joints during the execution of movements. Net joint moments have been calculated in the rehabilitation context in order to evaluate the gait patterns in children with cerebral palsy (LAI, KUO & ANDRIACCHI, 1998; ÖUNPUU, DAVIS & DeLUCA, 1996). It is the aim of this study to comparatively analyse the net joint moments in children and adults during walking and running in order to understand how the motor system deals with the external forces to better regulate the movements.

Methods

In order to estimate the net joint moments and to solve the indeterminancy problem, simplifications of the anatomic structure were adopted, grouping internal forces and moments around the chosen joints. Only the stance phases of walking and running were analysed for they are the most relevant in a loading analysis. Ground reaction forces, vertical torque and the location of the point of application of the ground reactions were measured with a KISTLER force plate (Kistler Instruments, Winterthur – Suisse, 1975). The segmental positions were measured with the SELSPOT II system (SELCOM AB, Partille – Sweeden, 1983). Both systems were synchronized and operated at a sampling frequency of 250 Hz. A biomechanical model to estimate joint axes and centers were associated with measures of the localization and orientation of the segments and ground reaction force data. The combination of the these measurements with the mathematical relations of the joints allowed the estimation of the net joint moments.

Three dimensional net joint moments were estimated for the ankle and knee joints at the sagittal and frontal planes, according to a static approach. Six children (average age = 6,5 ± 0,6 years-old; average height = 127,2 ± 8,4 cm) with no problems of orthopaedic or neurological nature participated in this study with their parent’s consent. The adults were sport students of the German Sports University of Cologne. The geometric relationships of the ankle and knee joint centers were determined using the models of INMAN (1976) and KAHLFUES (1971) respectively. They were combined with anthropometrical measurements and experimental data from the force plate and the SELSPOT system in order to calculate the net joint moments relative to the estimated joint centers. Each subject made at least five trials of walking and running in self-selected velocities. The trials were assembled averaged and means, standard deviations and coefficients of variation were compared between the child and the adult patterns.

Results & Discussion

The responses of one particular child and one adult as representative of the group are presented. The Figures 1 to 4 show the net joint moments obtained for one child selected from the group. His mean velocities were 1,44 ± 0,03 m.s⁻¹ for walking and 3,28 ± 0,28 m.s⁻¹ for running. For the adult, the mean

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1 This study was only possible with the supports of the DAAD (Germany), CAPES and UFSCar (Brazil).
velocities were 1.43 ± 0.3 m.s\(^{-1}\) and 4.3 ± 0.24 m.s\(^{-1}\) for walking and running respectively. The plotting convention adopted represents the effects of the external moments at the selected joints along the stance phases.

![Image](image1.png)

**FIGURE 1:** Five trials and mean curve of the net joint moments in the sagittal plane during walking of a child.

During walking and running, there is a small net plantar-flexor moment at weight acceptance and a dorsi-flexor moment predominates during most of the stance phase. The peak magnitudes of the net joint moments at the sagittal plane for walking and running patterns of the child are presented in TABLE 1.

<table>
<thead>
<tr>
<th></th>
<th>Ankle</th>
<th>Knee</th>
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<tbody>
<tr>
<td></td>
<td>Flexor</td>
<td></td>
</tr>
<tr>
<td>Walking</td>
<td>0.29 ± 0.08</td>
<td>1.4 ± 0.1</td>
</tr>
<tr>
<td>Running</td>
<td>0.44 ± 0.2</td>
<td>2.3 ± 0.1</td>
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The magnitudes of the net joint moments in the frontal plane were much less than those found in the sagittal plane and only their global patterns are discussed. During walking, there is a small net supination moment at the ankle at weight acceptance and a net pronation moment is dominant in the stance phase. At the knee, a net abduction moment acts during most of the stance phase. During running, a net pronation moment at the ankle and a net abduction moment at the knee dominate the stance phase.

![Image](image2.png)

**FIGURE 2:** Five trials and mean curve of the net joint moments in the frontal plane during walking of a child.

![Image](image3.png)

**FIGURE 3:** Six trials and mean curve of the net joint moments in the sagittal plane during running of a child.

![Image](image4.png)

**FIGURE 4:** Six trials and mean curve of the net joint moments in the frontal plane during running of a child.
The peak magnitudes of the net joint moments in the sagittal plane for the walking and running patterns of the adult are presented in TABLE 2.

<table>
<thead>
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<th>TABLE 2: Peak magnitudes of the net joint moments in the sagittal plane for the adult.</th>
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<tr>
<td>Net joint moments (Nm/kg)</td>
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<tr>
<td>Adult</td>
</tr>
<tr>
<td>Ankle</td>
</tr>
<tr>
<td>Plantar-flexor</td>
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<tr>
<td>Walking</td>
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<tr>
<td>Running</td>
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</table>

Normalization procedures for the net joint moments should also be discussed when comparing subjects of different ages and body dimensions, because the magnitudes of the moments are very sensitive to differences in the length of the lower limbs. In order to verify these influences the normalization procedure described by HOF (1996) was applied (Figure 5) to compare the net joint moment magnitudes of the child to those of the adult.

FIGURE 5: Net joint moments at the knee joint in Nm/kg and normalized by kg and leg length (Nm/kg/l) according to HOF (1996).

The quantitative results are very similar to those from other studies (ÖUNPUU 1990), which used more complex models. The normalization procedure reduces the magnitude differences between the net joint moments of the child and the adult and this effect was observed in the net joint moments determined for the sagittal and frontal planes for both movement patterns studied. The whole patterns of the net joint moments are not affected by the normalization procedure. A further discussion should focus on the relative contribution of the net joint moments to the understanding of some developmental trends in the coordination of locomotion in children.

References