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Hip and Knee Kinematics in Sagittal Plane during Stair Ascent and Descent in Children, Adolescents and Young Adults

by
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Ascending and descending stairs is a frequent activity in every-day living. Available data usually describe the ascent and descent pattern of young healthy adults, or elderly people.

In order to assess the problems of peadiatric patients during stair ascent and descent, and to evaluate how treatment changes this pattern, a normative data base is needed. This data is lacking in the literature. Therefore, the aim of this study was to collect the kinematic data of healthy children, adolescents and young adults during stair locomotion and to assess the changes in range of movement in hip and knee joints in the sagittal plane. Twenty-seven healthy subjects, aged 6 to 21 years old, participated in the study. The subjects were climbing stairs with dimensions comparable to steps in public building.

The data were collected using optoelectronic motion system VICON 460. Helen Hayes marker set and Plug-In-Gait model were used. The data were further processed using Polygon and Matlab softwares. The subjects were divided into 6 subgroups, according to their body stature.

Hip and knee kinematics in sagittal plane during stair ascent and descent are reported for all 6 subgroups.

The main factor determining the dynamic range of movement in the hip and knee joints during stair locomotion is the body stature / step height ratio. The present paper presents detailed data, which could be used as reference data for assessment of stair locomotion of paediatric patients.

Key words: stair locomotion, children, adolescents and young adults, reference data

Introduction

Ascending and descending stairs is a frequent activity in every-day, normal living. Available data usually describe the ascent and descent pattern of young healthy adults, or elderly people. A few papers investigated the changes occurring in kinematics and kinetics during stair ascent in healthy subjects (Yu et al., 1997; Nadeau et al., 2003; Protopapadaki et al., 2007). Stair climbing is a demanding task, which could increase the risk of falls in elderly population; therefore, some studies focused on stratergies used by older people to safely ascend and descend the stairs (Mian et al., 2007; Larsen et al., 2008; Reeves et al., 2008; Karamanidis et al., 2009).

Although adults and children encounter the task of stair locomotion in every day life in a similar way, the number of studies dealing with stair locomotion in children is limited. Some studies focused on the influence of orthotics on walking patterns of cerebral palsy (CP) patients and healthy children (Nahorniak et al., 1999; Sienko et al., 2002). In these studies, barefoot walking of the subjects was the control condition, and stair climbing with ankle-foot orthoses (AFOs) was used for experimental comparisons. One study investigated the influence of backpack weight on the kinematics of stair ascent using the pressure insole recordings for measurements (Hong & Li, 2005). Another study assessed how specific training changed the kinematics of children with Down syndrome during stair ascent and descent (Lafferty & Hons, 2005).

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The design of the stairs (step height and width, and stairs inclination) could influence the behaviour of the people who use them; therefore, this influence was also investigated (Mueller et al., 1998; Roys, 2001). Healthy subjects, before climbing the stairs, determine the relevant information about them. If subjects can choose between several types of stairs, they tend to keep certain parameters constant: the angle defined by the ratio between the height of the stairs and the distance taken from the foot to the top edge of the stair before the initiation of the movement (Cesari et al., 2003; Bertucco & Cesari, 2009). The reality of stair designs, however, is based upon state regulations for private and public buildings, and their dimensions are restricted within narrow limits. Therefore, children of different age and body dimensions have to climb the same stairs, despite their preferences.

Clinical practice reveals that some patients who walk relatively well on flat surfaces encounter problems while using the stairs. In order to assess the problems of peadiatric patients during stair ascent and descent, and to evaluate how treatment changes this pattern, normative data base is needed. This data is lacking in the literature. Therefore, the aim of this study was to collect the kinematic data of healthy children, adolescents and young adults during stair locomotion and to assess the changes in range of movement in hip and knee joints in sagittal plane.

Materials and Methods

Subjects

Twenty-five healthy children and adolescents, aged 6 to 18 years, both sexes, participated in the study. The data of 3 students, aged 20 to 21 years old were also included into the data base. The exclusion criteria were: any neurological problems in the past, diabetes, cardiac or pulmonary diseases, fractures or soft tissue trauma in the lower extremities, trunk or pelvis in the past. The study was approved by the local Ethical Committee and the participants and their parents (if needed) signed the informed consent form prior to the study.

The subjects' body stature ranged from 125 to 183.5 cm. The participants were divided into 6 groups, according to their body stature. In each group the stature range was 5 cm (apart from the highest, where the range was 8.5 cm).

Methods

The subjects were climbing stairs of step height 20 cm, and step width 29.5 cm (dimensions of the steps in public building, according to Polish regulations). The stairs were constructed especially for this study.

The data were collected using optoelectronic motion system VICON 460 with 6 cameras. Data were collected with 60 Hz sampling frequency. Helen Hayes marker set and Plug-In-Gait model were used.

The data were further processed using Polygon and Matlab softwares. Gait events were identified and all data were presented within the (stair) gait cycle. The data from left and right legs were pooled together in each subgroup, and the mean knee and hip kinematics in sagittal plane was calculated.

Results

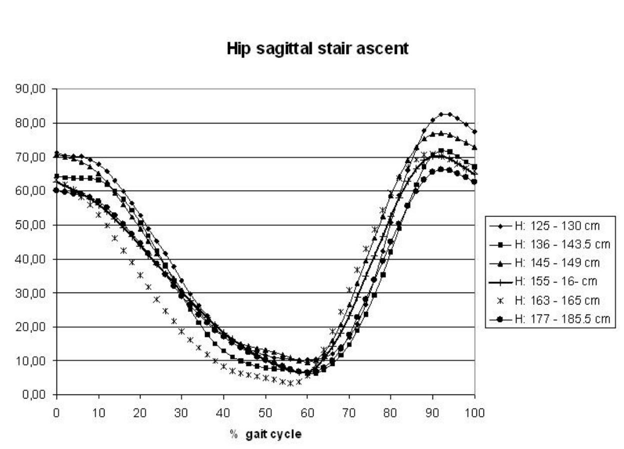

Figure 1
Hip kinematics during stair ascent, H – body stature

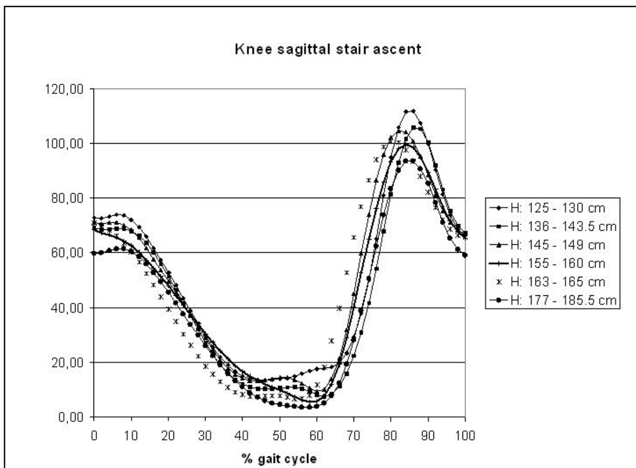

Figure 2
Knee kinematics during stair ascent, H – body stature

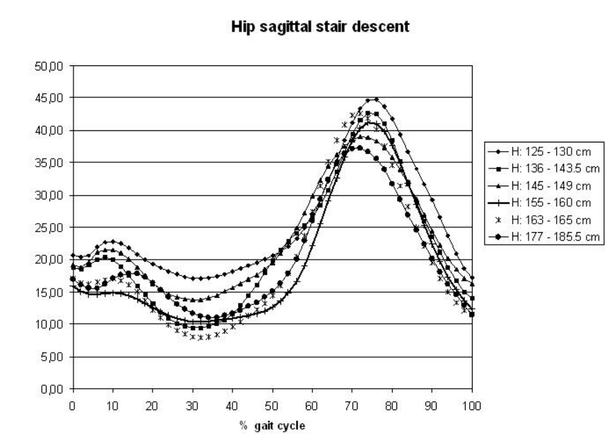

Figure 3
Hip kinematics during stair descent, H – body stature

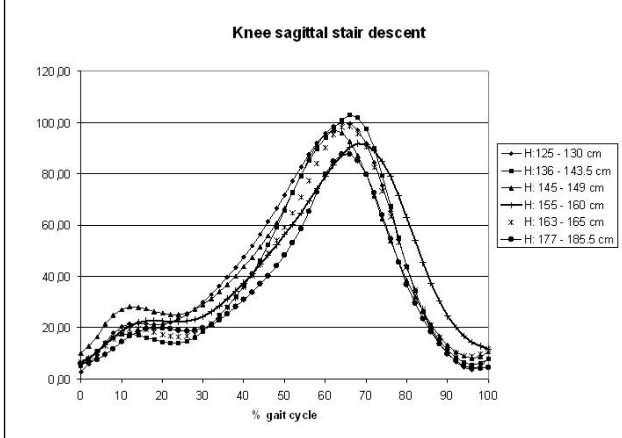

Figure 4
Knee kinematics during stair descent, H – body stature

Figures 1-4 show the results of hip and knee kinematics while ascending and descending the stairs. The results of all subgroups of different body stature are displayed on the same graph. Figures 1 and 2 show kinematics of the hip and knee while ascending the stairs; and figures 3 and 4 diagram the same variables while descending the stairs.

Tables 1 and 2 summarize the data of hip and knee motion during ascending and descending the stairs: maximum and minimum flexion, dynamic range of movement, maximum difference between the subgroups.

Discussion

The results show clearly that the body stature / step height ratio in children, adolescents and young adults influence the hip and knee kinematics while ascending and descending stairs. The biggest difference in the dynamic joint range was between the subgroups of the shortest and tallest body stature. Stair negotiation in the shorter group required much higher dynamic range of motion in these joints.

The results presented in Tables I and II show that the difference between the peak flexion in the sub-

Table 1
Summary of hip motion during ascending and descending stairs in children, adolescents and young adults

Results in hip joint											
	max hip flexion [°]		min hip flexion [°]		% of gait cycle with min hip flexion		hip range		difference in max hip flexion between groups (diffhip)	Diff hip/range [%]	
body stature [cm]	125 - 130	177 - 185.5	125 - 130	177 - 185.5	125 - 130	177 - 185.5	125 - 130	177 - 185.5		125 - 130	177 - 185.5
Body stature/ step height ratio	6.3 - 6.5	8.9 - 9.3	6.3 - 6.5	8.9 - 9.3	6.3 - 6.5	8.9 - 9.3	6.3 - 6.5	8.9 - 9.3		6.3 - 6.5	8.9 - 9.3
stair ascent	80	65	10	5	50-70	40-60	70	60	15	21	25
stair descent	45	35	20	10	30-40	30-40	25	25	10	40	40

Table 2

Summary of hip motion during ascending and descending stairs in children, adolescents and young adults

Results in knee joint													
	max knee flexion [°]		min knee flexion [°]		% of gait cycle with min knee flexion		% of cycle with max knee flexion		knee range		difference in max knee flexion between groups (diffknee)	%diff knee/range	
body stature [cm]	125 - 130	177 - 185.5	125 - 130	177 - 185.5	125 - 130	177 - 185.5	125 - 130	177 - 185.5	125 - 130	177 - 185.5		125 - 130	177 - 185.5
Body stature/ step height ratio	6.3 - 6.5	8.9 - 9.3	6.3 - 6.5	8.9 - 9.3	6.3 - 6.5	8.9 - 9.3	6.3 - 6.5	8.9 - 9.3	6.3 - 6.5	8.9 - 9.3		6.3 - 6.5	8.9 - 9.3
stair ascent	110	90	10	5	40-70	45-65	85	85	100	85	20	20	24
stair descent	95	85	20	20	15-45	15-25	65	70	75	65	10	13	15

groups of the shortest and tallest body stature reaches 15 degrees during ascent and 10 degrees during descent in the hip joint, and 20 degrees during ascent and 10 degrees during descent in knee flexion. This implies that this difference constitutes 20 - 40 % of the whole range of motion in hip joint, and 15 – 24 % in knee joint, which was not reported previously in the literature. This could explain the fact that some patients who do not have many difficulties in level walking have problems with stair locomotion.

Our results suggest, that the main factor determining the dynamic range of movement in the hip and knee joints during stair locomotion is the body stature / step height ratio. This paper presents detailed data, which could be used as reference data for assessment of stair locomotion of paediatric and young adult patients.

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