THE DYNAMICS OF LONGITUDINAL IMPACT TRANSMISSION AND ATTENUATION IN AMPUTEES RUNNING WITH BELOW-KNEE PROSTHESES

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INTRODUCTION: Lower limb amputees who want to stay physically active often encounter limitations related to the prosthesis they are wearing (Burgess, 1985; Burgess et al., 1983; Sanderson & Martin, 1996). These limitations become especially challenging when amputees want to rely on activities such as jogging or long distance running to improve their fitness level, and, doing so, aim for a better life quality (Broekhoff et al., 1986; Hittenberger, 1986; Miller, 1981; Sanderson & Martin, 1996).

The loss of an important amount of the biological tissues attenuating the foot-ground repetitive impact shocks can possibly lead to severe health problems like cartilage degeneration, stress fractures and even be a contributing factor in the development of lower back pain (Czerniecki et al., 1996; Enoka et al., 1982; Got, 1987; Therrien et al., 1982; Voloshin & Wosk, 1981). Since the wearing of a prosthesis is considered to alter the overall locomotion dynamics of an individual (Czerniecki et al., 1996), and since asymmetrical gait has even been associated with degenerative changes in the intact limb (Hurley et al., 1990), it becomes imperative to study the different aspects of the human body response in such a situation.

The present research on the longitudinal impact attenuation dynamics of amputees running with below-knee prostheses was undertaken in order to determine shock transmission phenomena above and below the ankle and knee joints. More specifically, it intended to compare total body accelerations as well as accelerations measured at ankle and hip levels in both the prosthetic and the sound legs.

METHODS AND PROCEDURES: A group of six (6) below-knee amputees, wearing a prosthesis for two (2) years or more and exhibiting a flight phase in their running pattern, was used for the study. Subjects included four (4) males and two (2) females ranging from 9 to 32 years old, and from 39 to 89,5 kg. They were considered in good health and were free of neurological problems. Their prosthetic leg was fitted with a Solid Ankle Cushion Heel (SACH) foot. Subjects completed practice trials to become accustomed to the task and data collection process. Five (5) trials for each leg were evaluated while running at a speed between 2.8 and 3.2 ms^{-1}. Impact shock was measured with accelerometers placed at ankles and hips, as well as with a force platform.

Global longitudinal shock was calculated from the vertical component of ground reaction force at impact, while shock transmitted to ankle and hip was obtained from respective accelerometer signals. A Delta value (representing the difference between the shock measured at the ankle and the shock registered at the hip level) was computed as an indicator of shock attenuation along the leg. Data were collected on-line and analyzed with Ariel APAS software. (A kinematic study from

the sagittal plane and frontal plane video recordings of one full running stride over the force platform for each trial complemented the kinetic study but is not presented in this paper).
A statistical analysis of results was performed with the traditional analysis of variance technique, and a 0.05 confidence interval was selected as the significance level for differences between the computed means of the five (5) trials, for each parameter and leg condition.

RESULTS AND DISCUSSION: Preliminary descriptive statistics (Table 1) disclose global body accelerations in the same range, but slightly lower, than those calculated by Sanderson and Martin (1996) for below-knee amputees, as well as those reported by Therrien et al. (1982) for non-amputee subjects. Accelerations measured at the ankle ranged from 7 to 30 g's for the prosthetic leg and from 9 to 25 g's for the sound limb, while large standard deviations accounted for a wide variability between subjects.
Statistical analysis of results did not disclose any significant difference between accelerations in the prosthetic leg and those in the sound limb (Figure 1). However, shock transmitted at the hip level was significantly lower in both the prosthetic and the sound limbs. These results could probably be explained by the fact that less experienced amputee runners (3 out of the 6 subjects) have a tendency to protect the prosthetic limb and apply less load on it (Miller et al., 1984), while others have a tendency to contact the ground with the prosthetic knee close to full extension and closer to a vertical position (Sanderson & Martin, 1996).

CONCLUSIONS: Within the scope and limitations of the present study (small number of subjects, lack of homogeneity of subjects in age, weight and running ability, use of a SACH prosthetic foot), results have shown that impact shock transmitted from ankle to hip is attenuated in both the prosthetic and the sound limbs, even if the materials and the mechanisms responsible for the absorption are different. It was also demonstrated that subjects who had attained higher running ability through the rehabilitation process were applying larger loads on the prosthetic limb, rather than protecting it, as many amputees do. Conclusions of the present study as well as from recent literature indicate that after adequate rehabilitation amputees wearing prostheses well adapted to their specific needs can effectively participate in many physical activities involving repetitive longitudinal impacts.
Further studies should include investigation of the shock attenuation efficiency of dynamic response foot prostheses in more active amputees with a higher level of running skill.

Table 1: Intensity of shocks (g) transmitted through prosthetic leg (PL) and sound leg (SL)

	DELTA		**GLOBAL**		**ANKLE**		**HIP**	
	PL	**SL**	**PL**	**SL**	**PL**	**SL**	**PL**	**SL**
MEAN	2,00	2,17	15,52	15,15	6,21	6,62	9,30	8,49
SD	0,22	0,42	3,94	2,63	2,06	1,51	4,92	1,13

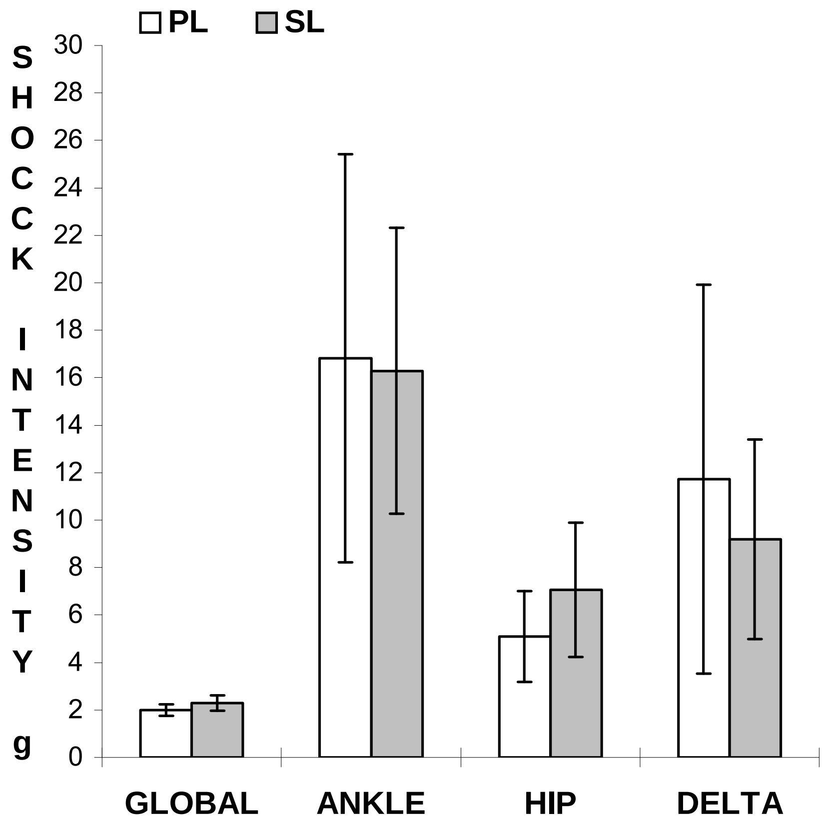

Figure 1: Mean and SD of shocks transmitted through prosthetic leg (PL) and sound leg (SL)

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