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NORMAL CYCLE GAIT ANALYSIS USING A FORCE PLATE

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ABSTRACT
The purpose of this paper is to perform a biomechanical analysis of a human normal cycle gait of some subjects with a body weight between 55 and 90 kg. The biomechanical analysis is presented to determining ground reaction forces (Fx, Fy, Fz) and moments (Mx, My, Mz) during normal human walking based only on anthropometrical data and a force plate. The pressures sensed by the transducers during a movement are captured on computer, and a graphical display is typically used to provide an indication of the time-history of the reaction forces over the contact surface.
Keywords: biomechanical analysis, force plate, gait cycle, normal walking.

1. INTRODUCTION
Ground reaction forces devices enable measurement of the total force vector manifested in various locomotor activities during contact between the subject's body (typically the foot) and the surface (floor) in which the device is embedded. Also, the device usually gives the moment of force vector al well as planar coordinate x and y of the point center pressure as its output. These measurement quantities may be displayed as time curves. As such, the device is generally applicable in locomotion studies, healthy or pathological. Besides being used in dynamic phenomena such as gait and running, force platforms (force plates) may also be used in measurements of approximate static body posture since, because body support via the feet is nearly fixed, measurement signal are a consequence of movement of the body's center of mass. This is exploited, for instance, when testing the vestibular apparatus from neurogical and otorhinolaryngological standpoint, in general, when examining postural stability and balance [1][4].

2. EQUIPMENT DESCRIPTION
The equipment used to analyze the normal cycle gait consists of *force plate by Kistler,* a *signal amplifier, two acquisition boards* (for analogue and digital signals) and a *data acquisition system* (laptop) (figure 1) [3].
The force plate is a device equipped with four force sensors (piezoelectric sensors), each positioned in one corner of the platform. Each sensor executes a distinct measurement and the final signal, which is transmitted to the amplifier, represents the resultant measurement effectuated by all four sensors. The calibration of the force plate was made before starting the measurements using a gauge weight of 10 kg, and the smoothness of the surface was verified using a balance level [3][4]. Under the external force induced by the subjects, the piezoelectric sensors deform themselves transforming the mechanical action into the electrical signal. This signal, initial in milivolts, is received and amplified by the ***signal amplifier***. The amplifier is a classical DC amplifier with capacitive feedback, having the roll to transform the output data of the pressure sensors into the tension standard signals (tension between ± 1V and ± 10 V with low impedance), to effectuate the compensation of the sensors characteristics and to limit the frequency to the exact domain.
For the conversion of the analogue/digital signals we used two ***acquisition boards***, respectively PC CARD DAS 16/16 and PC CARD D24/CTR3 [2][3].

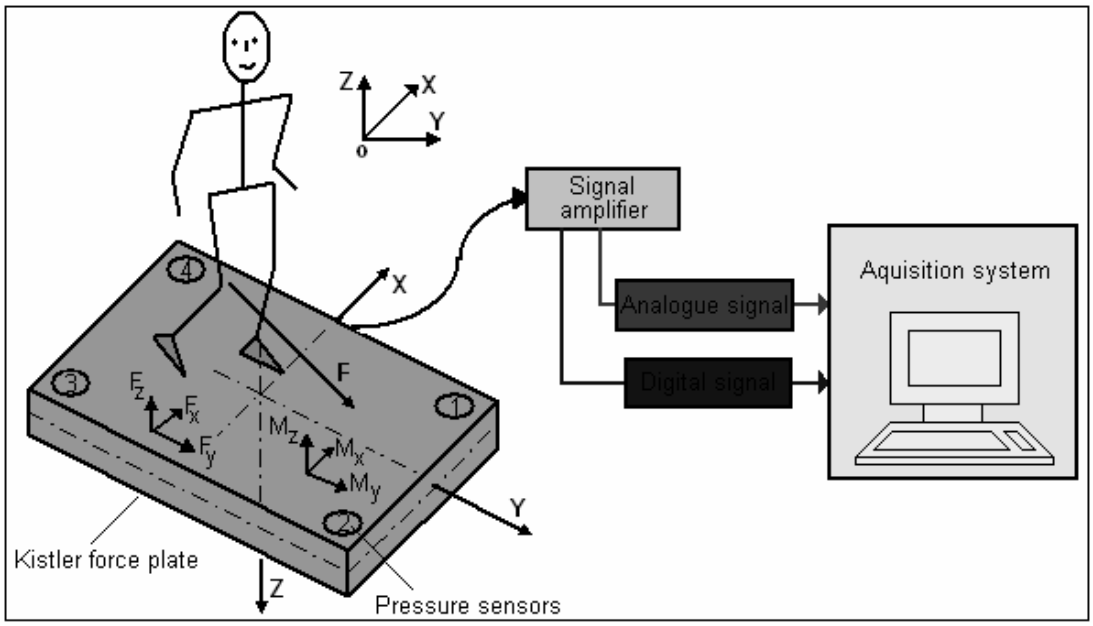

Figure 1. Equipment description used for measuring the reaction forces and moments during normal cycle gait

3. EXPERIMENT DESCRIPTION

The purpose of this paper is to perform a biomechanical analysis of a human normal cycle gait, in normal conditions (no efforts during experiment), of four subjects (three males and one female) with a body weight between 55 and 90 kg. The biomechanical analysis is presented to determining ground reaction forces (Fx, Fy, Fz) and moments (Mx, My, Mz) for the right foot during normal human walking (4km/h) based only on anthropometrical and physiological data and a force plate [3].

Before starting the experiments the subjects were measured to determine the physiological parameters. In table 1 are written the anthropometrical and physiological parameters of all subjects.

The subjects were subjected each for a number of three tests for normal cycle gait using the right foot as attack foot on the plate. The registration time of the measurements experiment is 10 seconds with a work frequency of 250 Hz. The subjects did not wear anything on their feet during the experiment. The concluding results of the reaction forces and the moments are written in the table 1, respectively graphly displayed (figure 2, 3, 4, 5).

Table 1 Physiological and gait parameters of all subjects in normal conditions.

Physiological parameters								
		Subject 1		**Subject 2**		**Subject 3**		**Subject 4**
Sex [M/F]		F		M		M		M
Age [years]		23		24		23		23
Weight [kg]		63.37		71.58		86.3		55.81
Height [m]		1.53		1.78		1.73		1.70
Arterial pressure [mmHg]		12.3/6,7		16.8/11.8		16.8/9.1		15.0/9.0
Pulse [bits/min]		71		89		86		87
Temperature [°C]		37.6		37.4		37.2		37.2
Gait parameters								
		Subject 1		**Subject 2**		**Subject 3**		**Subject 4**
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Reaction forces	F_x [N]	-31.70	44.84	-45.78	65.76	-46.47	76.47	-31.26	60.55
	F_y [N]	-75.76	96.76	-55.13	91.18	-71.48	146.83	-45.68	94.25
	F_z [N]	102.05	771.69	113.5	827.82	134.50	968.32	103.96	695.75
Moments	M_x [Nm]	-126.96	116.10	-168.53	101.59	-176.11	178.36	-121.59	116.99
	M_y [Nm]	-51.02	42.08	-95.49	87.89	-99.38	74.95	-59.51	57.35
	M_z [Nm]	-12.83	5.90	-7.27	29.37	-19.91	9.49	-15.34	4.39

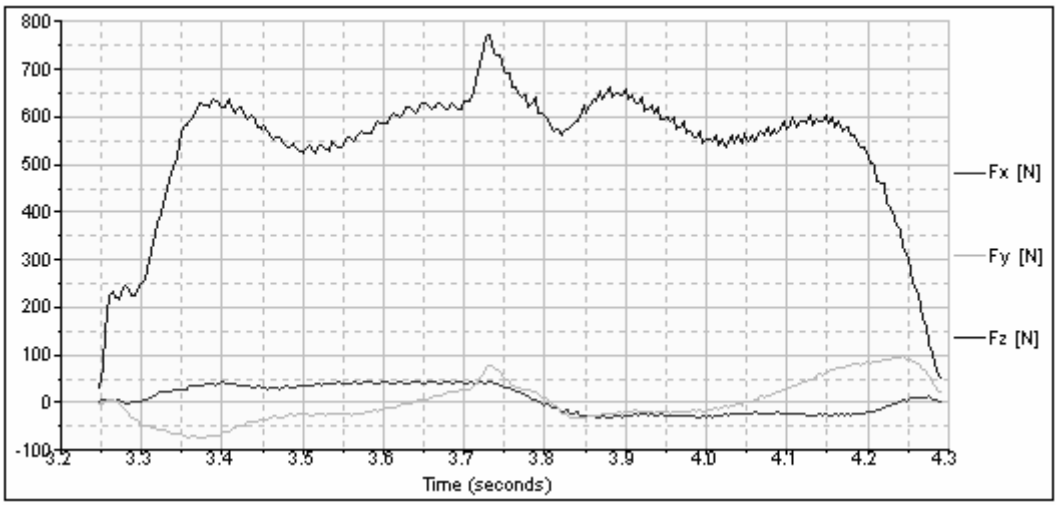

Figure 2. Right foot ground reaction forces of subject 1 during normal cycle gait

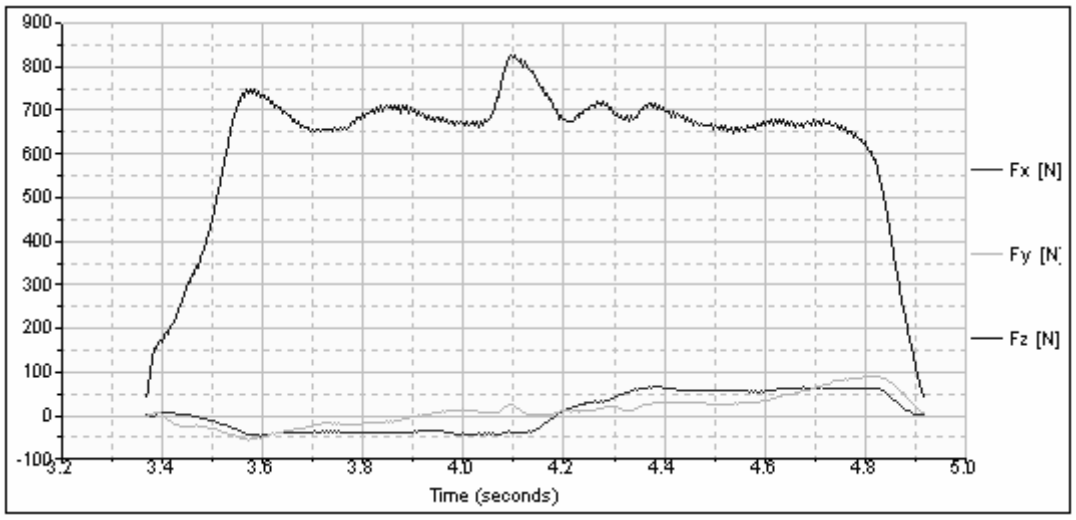

Figure 3. Right foot ground reaction forces of subject 2 during normal cycle gait

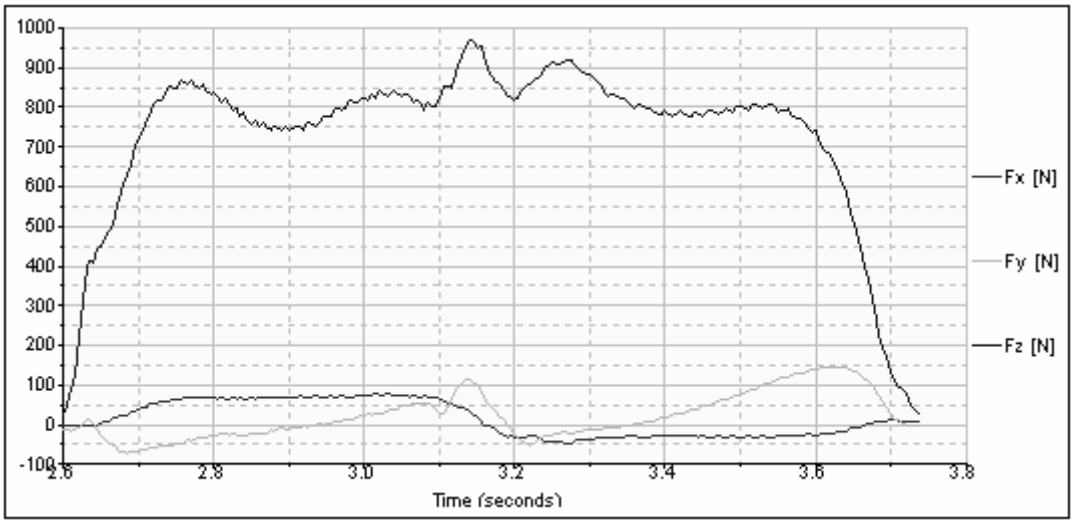

Figure 4. Right foot ground reaction forces of subject 3 during normal cycle gait

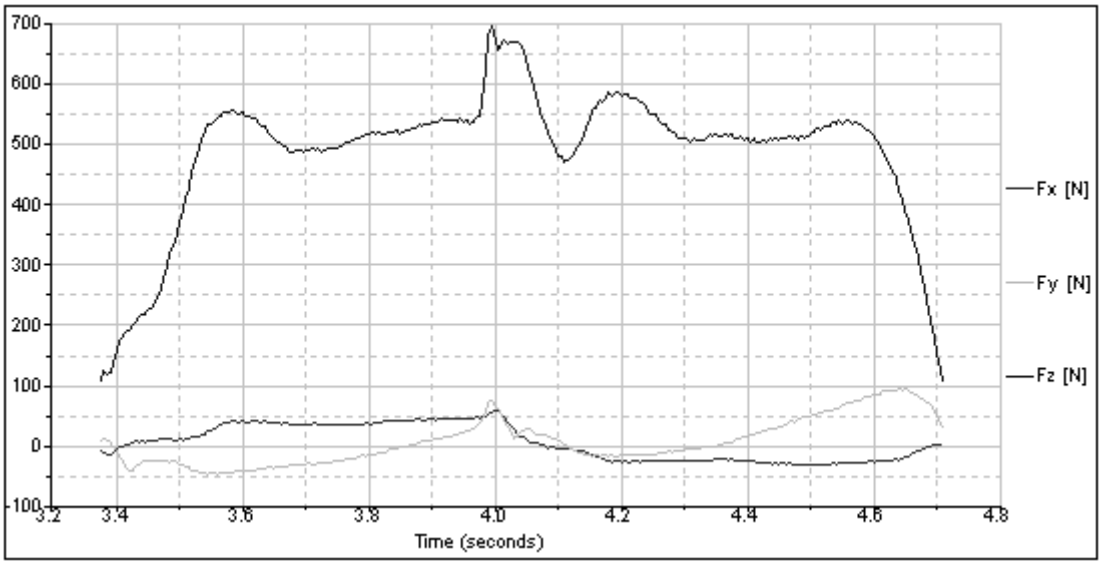

Figure 5. Right foot ground reaction forces of subject 4 during normal cycle gait

4. CONCLUSIONS

In walking, for all subjects, the vertical ground reaction forces F_z shows a characteristic waveform with four maximal and two local minimum between, occurring approximately through the support phase. This instant marks the amortization of vertical body movement by the knee joint activity. The first maximum represents the right heel attack on the plate, the second one represents the toe take off of the right foot, third maximum represents the left heel attack on the plate and the fourth maximum represents the toe take off of the left foot. As it can see, there is a middle maximum value, which represents that the directory foot of all subjects is the right foot, because the push of period value of right foot is much higher then the left foot.

Inspecting the horizontal forces signal (F_x, F_y) it can be seen some fluctuations during walking, that because the foot has an irregular form and it is an elastic medium. Also, during walking between foot surface and plate surface appear other forces like superficial tension force, which is induced by the protector thin layer of the foot skin and the vacuum force, which is induced in some foot cavities. These forces are higher then the walking forces and keeps the foot in contact with the plate surface.

5. REFERENCES

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