THE SYMMETRY IN GAIT KINEMATICS OF ADOLESCENTS' CASE STUDIES

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A gait cycle of 20 adolescents has been analyzed, representing each of them an age-gender group within a period of five years. The basic step values, the flexion-extension angle values between trunk and thighs (hips), thighs and calves (knees), calves and feet (ankles), and the angle between the horizontal and thighs were calculated. The symmetric movements of the lower limbs of each individual can be observed by means of angle-angle diagrams and the statistical results indicate the significant differences between right and left joints. After the analysis it is possible to infer that the symmetry in walking is developed during the latest years of the adolescence, but there are significant differences between right and left angular displacements.

KEY WORDS: gait symmetry, adolescents, angular displacement

INTRODUCTION: During the childhood period the abilities of the movement depend on the development and the maturation of muscles, bones and nerves. The physical activities of the developing child influence the size, the form and the alignment of the muscle skeletal system (Skinner, 1994). Much of the human variability appears to be related to the answers to the stressors, and there are diverse answers: cultural, growth and of development. Also there are variations because the bilateral symmetry in the structure of the human body. The variation in the left and right side is random and also independent. There exists variability in the time required for the maturation of the individual's biological systems; the individual grows while she or he matures (Malina, 1991). The fast growth during adolescence is a phenomenon in all the individuals, and varies in intensity and duration from a child to another one (Tanner, 1966). The commonly accepted duration of adolescence is almost five years (Comas, 1976; Stang, 2008).

The case study, this is a single subject study, is a necessary and sufficient method for certain important tasks of investigation (Flyvbjerg, 2006). This means investigation of single case study or multiple case studies, that can include quantitative evidences are trustworthy sources of multiple evidences and are beneficiaries of previous theoretical development (Yin, 2002). It is not desirable to summarize and to generalize case studies but, it must be emphasized that the method contributes to the knowledge development (Flyvbjerg, 2006).

A comfortable speed means that the rate of movement is free, that each individual walked at the speed that he or she wants (Kerrigan et al., 1998). It has been studied that free walking (comfortable speed) was far less variable than forced walking varied with speed. It has been reported that when walking at freely chosen step rate, there is an invariant relationship between step length and step rate regardless of walking speed. Many observations have confirmed that the rhythmic stage of human walking is very consistent and is directly related to the optimal efficiency for an individual (Sutherland et al., 1994).

When walking and/or running the knee flexion-extension is related to the thigh rotation (forward and backward) of the same lower member, by means of angle-angle diagrams (Cavanagh and Grieve, 1973M; Enoka et al., 1982). This graphical representation is sensitive to details of movement and useful to show the range of movement magnitude (ROM), the differences between the right step and the left step, and therefore, these graphs indicate the magnitude of the individuals' gait asymmetry.

The calculations of the three-dimensional kinematics, by means of photogrametric and videogrametric procedures, need at least two simultaneous recordings in video from different views. Additionally, the DLT procedures could be used for the individuals'

movement 3D reconstruction in a computer (Woltring, 1980; Shapiro, 1978; Espinosa, 1999). Commonly the human body representation with 14 linear segments is the Chandler inertial model (Chandler et al., 1975). The movement sequence analysis is for a gait cycle considered of the double support and the single support or oscillation phases (Vaughan et al., 1992).
There is the necessity to know how is developed the kinematics of walking while the adolescence period passes. The objective of this research has been to find in the analyzed sample, the asymmetries and differences in the angular displacements of the gait. This work can be useful in the considerations that the physical educator, the sport trainer and/or the physician, could do with respect to their criteria of education and diagnosis.

METHODS: Participants. This study is a cross-sectional one carried out in Mexico City with a population belonging to the middle socioeconomic layer. The sample of analyzed individuals (Table 1) is constituted by 20 case studies representing each of them an age-gender group within a period of five years that is the accepted duration of adolescence. **Data collection.** Three camcorders (Panasonic AG-EZ30 DV) were installed in a tripod separated to each other by an angle of 120 degrees, each with its focus line aiming towards the same target at a distance of 10 m that is the center of the path by which the adolescents walked. The individuals were asked to walk barefoot at a comfortable speed through the path of about 10 m long and 1.5 m wide, the more centered gait cycle was chosen. The source data were the coordinates of 19 anatomical points that were located and extracted from the video images. No markers were used to locate the anatomical points. The 3D data was approximated to 120 calculated frames per second by cubic beta-spline interpolation. **Data analysis.** The 3D angular displacements and the basic values of walking of the 20 individuals were calculated by means of computer programs developed for this purpose. The differences of the relation of the knee flexion-extension and the thigh rotation were observed in angle-angle diagrams. The Student's t-test was used to compare the performance between right and left lower limbs.

Table 1. Age and gender groups and individual cases.

FEMALE	GROUP	10f	105f	11f	115f	12f	125f	13f	135f	14f	145f
AGE	[years]	10.23	10.59	11.05	11.68	12.11	12.58	12.95	13.73	13.85	14.52
MALE	GROUP	12m	125m	13m	135m	14m	145m	15m	155m	16m	165m
AGE	[years]	11.97	12.66	13	13.73	14.09	14.34	15.06	15.62	15.83	16.72

RESULTS AND DISCUSSION: The basic step values: duration, length, rate and velocity, were calculated and are shown in Table 2. In average the male individuals use a more time to execute a gait cycle, they have a longer step length, and their step rate and velocity are slower. The differences between the female and male individuals and between the right and the left side are a few hundredths for most of the cases.
The angle-angle diagrams indicate how much symmetric are the knee-thigh relations, right side and left side. In Figure 1 the differences can be identified visually, the figure shows that the most marked asymmetries are those of the youngest individuals: female 10f, 105f, 11f and 115f, and male 12m, 125m, 135m and 145m. Although, making an only visual consideration it is possible to say that the knee flexion-extension and the thigh rotation ranks of movement are analogous in both genders.
The Student's t-test ($p<0.05$) was applied to analyze the differences in the angular displacement between right joints and left joints, and both thighs inclination of each one of the 20 individuals. There are significant differences at a 0.05 level of significance if the t* score of the statistic student lies outside the range -1.96 to 1.96. The Table 3 shows for the female individuals: the 100% of hips, the 70% of knees and of ankles, and the 20% of thighs have differences; for the male individuals: the 100% of hips, the 60% of knees, the 90% of ankles, and the 20% of thighs have differences.

Table 2. Right and left step duration, length, rate and velocity for both female and male individuals.

	ID	10f	105f	11f	115f	12f	125f	13f	135f	14f	145f
Right	t [s]	0.53	0.49	0.42	0.4	0.48	0.41	0.48	0.44	0.55	0.46
step	length [m]	0.69	0.64	0.82	0.67	0.87	0.72	0.62	0.7	0.62	0.66
	rate [steps/s]	1.89	2.04	2.38	2.5	2.08	2.44	2.08	2.27	1.82	2.17
	v [m/s]	1.3	1.31	1.95	1.68	1.81	1.76	1.29	1.59	1.13	1.43
Left	t [s]	0.52	0.47	0.41	0.38	0.46	0.4	0.45	0.42	0.52	0.49
step	length [m]	0.62	0.62	0.8	0.68	0.75	0.65	0.65	0.72	0.6	0.66
	rate [steps/s]	1.92	2.13	2.44	2.63	2.17	2.5	2.22	2.38	1.92	2.04
	v [m/s]	1.19	1.32	1.95	1.79	1.63	1.63	1.44	1.71	1.15	1.35
	ID	12m	125m	13m	135m	14m	145m	15m	155m	16m	165m
Right	t [s]	0.49	0.55	0.6	0.44	0.43	0.59	0.5	0.48	0.5	0.4
step	length [m]	0.7	0.65	0.76	0.7	0.8	0.65	0.7	0.74	0.7	0.79
	rate [steps/s]	2.04	1.82	1.67	2.27	2.33	1.69	2	2.08	2	2.5
	v [m/s]	1.43	1.18	1.27	1.59	1.86	1.1	1.4	1.54	1.4	1.98
Left	t [s]	0.47	0.59	0.49	0.44	0.41	0.62	0.44	0.47	0.51	0.4
step	length [m]	0.66	0.67	0.68	0.68	0.84	0.6	0.62	0.74	0.61	0.7
	rate [steps/s]	2.13	1.69	2.04	2.27	2.44	1.61	2.27	2.13	1.96	2.5
	v [m/s]	1.4	1.14	1.39	1.55	2.05	0.97	1.41	1.57	1.2	1.75

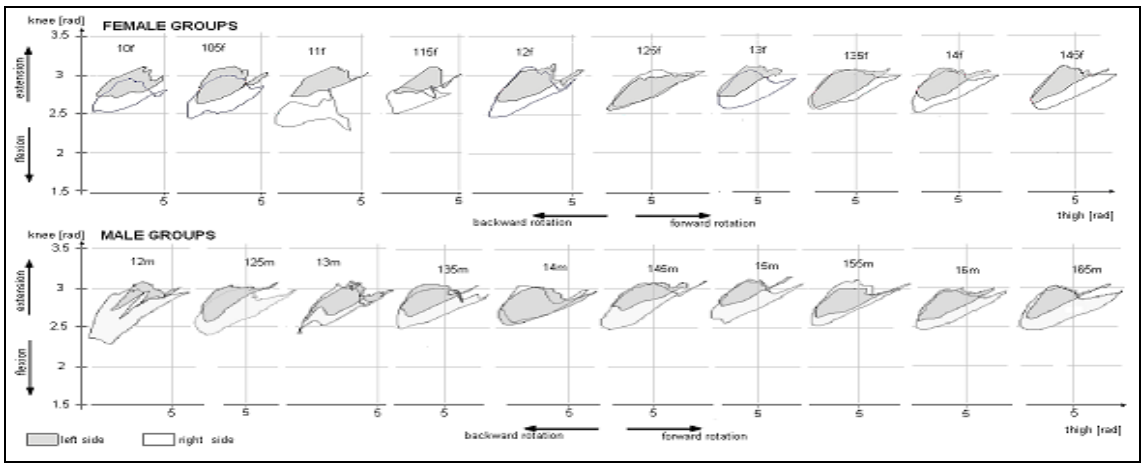

Figure 1. Angle – angle diagrams. The relation between the knee flexion - extension and the forwards and backwards thigh rotation.

Table 3. The Student's t-test statistic comparing right and left joints

Joints	10f	105f	11f	115f	12f	125f	13f	135f	14f	145f
HIPS	22.1*	-11.6*	-20.8*	-14.2*	-6.6*	-5.2*	-20.2*	-12.6*	-7.9*	-8.0*
KNEES	-7.9*	-6.4*	-21.7*	-12.6*	-3.8*	2.3*	-4.4*	-0.1*	-1.9*	-1.9*
ANKLES	-1.4*	3.7*	11.7*	-0.6*	0.8*	19.2*	8.7*	13.2*	3.9*	3.0*
THIGHS	1.1*	1.1*	3.6*	3.8*	1.8*	-0.6*	-0.4*	-0.7*	0.8*	0.4*
Joints	12m	125m	13m	135m	14m	145m	15m	155m	16m	165m
HIPS	-8.4*	-16.0*	2.1*	-13.6*	-4.3*	-16.7*	-14.1*	-8.4*	-11.5*	-11.2*
KNEES	-7.1*	-4.7*	-1.9*	-4.1*	-0.4*	-4.3*	-4.4*	1.1*	-1.9*	-3.7*
ANKLES	-3.9*	9.0*	0.5*	14.8*	12.1*	8.3*	10.5*	7.3*	9.5*	7.2*
THIGHS	3.1*	-1.7*	0.8*	-2.1*	-1.4*	0.3*	-0.1*	-0.9*	0.3*	0.3*

*$p<0.05$

CONCLUSION: The results of this study indicate that during the adolescence period, there are slightly differences in the basic step values between genders. The ranges of movement in the knee flexion-extension and thigh rotation relation, inferred that the symmetry in walking is developed during the latest years of the adolescence. Comparing the joints of the lower limbs, there are about 70% of significant differences between the right angular displacements and the left angular displacements.
It will be necessary to analyze a significant group of individuals for each age and gender group in order to know if the angular kinematic parameters provide the sufficient information to establish behavior patterns.

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Acknowledgement
The author would like to thank my former tutor Johanna Faulhaber for her confidence in my effort.