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Effects of Arm Swing and Dominance on Various Gait Parameters in Children

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Abstract

Background: Human gait has always been a topic for researchers' interest. The lower extremities and its movement with regards to the head, arms and trunk as a single unit is usual task for the study purpose. Meanwhile, where arm movements have received virtually no attention. There is considerable evidence that arm swing is an essential component of locomotion for human walking. Walking without arm swing increases the metabolic cost of walking. It results either because of the greater angular momentum about the vertical that needs to be counteracted, or maybe because of the larger vertical movements of the center of mass that occur when the arms do not swing upward when the trunk moves downward. The literature suggests that, arm swing during human locomotion enhances gait stability. The gait variations in pediatric age group, is observed due to growth and development of child's body. Following study was conducted to find out whether arm swing has the same effect on gait in pediatric age group as it has on adults. Another objective was to find out the dependency of hand dominance on gait cycle in children.

Method and Results: Twenty children were assessed for their gait parameters in relation with their natural arm swing, restricting dominant arm swing and bilateral arm swing restriction. ANOVA test was used for the statistical analysis. There was extremely significant difference observed in gait parameters (step length, stride length and step width) while allowing normal arm swing, with dominant arm bound and with both arm bound.

Conclusion: There is impact of dominance of arm and arm swing of gait parameters in children.

Keywords: Gait parameters; Arm swing; Arm dominance

Introduction

Human locomotion or gait is described as a translatory progression of the body as a whole. It is produced by coordinated rotatory movements of body segments [1]. The lower extremities support it by alternating movements and carry along the head, arms, and trunk [2]. A gait cycle is the time interval between two successive events of the same limb. Usually it progresses by initial contact (also called heel contact or heel strike) of the lower extremity with the supporting surface. Each extremity during one gait cycle, passes through two major phases as a stance phase (when some part of the foot is in contact with the floor, which makes up about 60% of the gait cycle) and a swing phase (when the foot is not in contact with the floor, which makes up the remaining 40%) [3,4]. Between the time one limb makes initial contact and the other one leaves the floor at toe off, there are two periods of double support. Heel strike, foot flat, mid stance, heel off and toe off are the phases involved in stance phase. Swing phase involves, the acceleration, mid swing and deceleration [4].

Time and distance are two basic parameters of motion. The measurements of these variables provide a basic gait description. Stance time, single-limb and double-support time, swing time, stride and step time, cadence, and speed are the time dependent variables. Stride length, step length and width, and degree of toe-out are the distance variables. These measurements are referred as the "basic gait parameters" and the "vital signs of walking". This statement reflects the fact that these measurements are very useful indicators that to find out abnormal gait patterns and also the extent of that abnormality, without necessarily indicating the cause of the problem [5].

Stance time is known as, the amount of time that elapses during the stance phase of one extremity in a gait cycle. The time that elapses during the period when only one extremity is on the supporting surface in a gait cycle is single-support time. Double-support time is the time spent with both feet on the ground during one gait cycle. Double support time may be increased in elderly persons and in people with balance disorders. Stride length is the linear distance between two successive events that

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are accomplished by the same lower extremity during gait. In general, stride length is measured as the linear distance from the point of one heel strike of one lower extremity to the point of the next heel strike of the same extremity. Stride duration is the amount of time it takes to accomplish one stride. Stride duration and gait cycle duration are synonymous. For a normal adult, one stride lasts approximately for one second. Step length is the linear distance between two successive points of contact of opposite extremities. It is usually measured from the heel strike of one extremity to the heel strike of the opposite extremity. Step duration is the amount of time spent during a single step. Measurement of step duration is expressed as seconds per step. In the cases of weakness or pain in an extremity, step duration may be decreased on the affected side and increased on the unaffected side. Cadence is the number of steps taken by a person per unit of time. Cadence is measured as the number of steps per second or per minute. A shorter step length will result in an increased cadence at given velocity. Step width is measured as the linear distance between the midpoint of the heel of one foot and the same point on the other foot. When there is an increased demand for side-to-side stability, step width increases. It is commonly observed in elderly persons and in small children. Degree of toe-out represents the angle of Foot Placement (FP). It is measured as the angle formed by each foot's line of progression and a line intersecting the center of the heel and the second toe. The angle for men is about seven degrees [6,7].

There is difference between the gait of small children and gait of adults. The main ways in which the gait of small children differs from that of adults are as follows: (1) the wide walking base (2) the stride length and the speed are lower and higher cadence (3) small children have no heel strike and initial contact made by the flat foot (4) there is very little stance phase knee flexion (5) during the swing phase, the whole leg is externally rotated (6) absence of reciprocal arm swinging. These differences in the gait mature at different rates. The characteristics (3), (4), (5) change to adult patterns by age of 2 years, and (1) and (6) at the age of 4 years. The cycle time, stride length and speed continue to change with growth reaching normal adult values around the age of 15 [8].

Collins et al. (2009) and Pijnappels et al. (2010), hypothesized that (1) arm swing has no effect on the local stability of steady-state gait, (2) the initial phase of global gait stability indicates that walking with normal arm swing is less stable, and (3) the reactive phase of global gait stability indicates that walking with normal arm swing leads to a better recovery following an external perturbation, as quantified by the rate of return to normal walking pattern [6,9].

Methodology

The study was conducted on 20 children in the age group of 6 to 12 years (12 males and 8 females) who agreed to participate voluntarily. Out of the 20 children 12 were right had dominant and 8 were left hand dominant. A written consent was taken from the children's parents and their teachers and the procedure was explained to them. The children were made to walk a distance of 10 feet first while allowing normal bilateral arm swing, followed by restricting the dominant arm swing with a binder and lastly by restricting the arm swing of both the arms. In the ultimate trial where the arm swing of both arms was restricted, the children were told to fold their arms across their chest, and interlock their forearms. Each hand was supported on the flexed elbow of the contralateral arm and was told to let the arms hang in a relaxed manner and to avoid tensing the shoulder and arm muscles. The data was collected and the temporal and spatial parameters

Table 1: Average values of step length with normal arm swing, dominant arm bound and with bilateral arm bound.

Test	Step Length with Normal arm swing (A)	Step Length with Dominant arm bound (B)	Step Length with Bilateral arm bound (C)
Average	34.7	40	34.45

Table 2: The average values of Stride Length with normal arm swing, dominant arm bound and with bilateral arm bound.

Test	Stride Length with Normal arm swing (A)	Stride Length with Dominant arm bound (B)	Stride Length with Bilateral arm bound (C)
Average	75.1	62	73

Table 3: The average values of Step width with normal arm swing, dominant arm bound and with bilateral arm bound.

Test	Step Width with Normal arm swing (A)	Step Width with Dominant arm bound (B)	Step Width with Bilateral arm bound (C)
Average	15.8	15.65	14.45

(step length, stride length, step width, cadence) were calculated and compared with each trial of each participating individual.

Data analysis and interpretation

The collected data has been tabulated (Table 1-7) and formulated for the analysis. As the data needed parametric test, ANOVA test is used for analysis. The p value is less than 0.0001 and is considered extremely significant.

Discussion

The study was intended to analyze the effect of arm swing and dominancy on children for the variability of step length, stride length and step width. The analysis showed extremely significant difference in step length, stride length and step width while allowing normal arm swing, with dominant arm bound and with both arm bound. It was seen that the step length, stride length and step width had decreased when both arms were bound. It was also seen that cadence increased as the age increased from 6 to 12 years.

In very young children, due to immature control of posture and gait, unsteady locomotion is resulted. Maturity of gait relatively appears in children of ~3 yr of age. As the stride dynamics depend on neural control, it was hypothesized that beyond age 3, motor control would continue to develop. Measurements of stride-to-stride variability are increased as the age progresses. Also, the measurements of the temporal organization of gait also show significant age-dependent changes. Thus the findings indicated that mature stride dynamics may not be completely developed even in healthy 7 yr old children. It also suggests that different aspects of stride dynamics mature at different ages [10,11].

When young children first begin to walk, due to immature control of posture and gait, stride-to-stride fluctuations and frequent falls are observed. As the age progresses, their gait is relatively matures and the visually apparent unsteadiness is replaced by a more stable walking pattern [5,12]. Subtle changes in the development of neuromuscular control and locomotor function continue beyond age 3 during developmental process. Some studies suggest a decrease in walking variability after this age [2,13].

There is need of further research to explain the complex age-related changes in the magnitude and temporal structure of stride dynamics. Present findings have potentially important implications for the understanding and modeling of the integrative control of

Table 4: Comparison of the differences in the step length with normal arm swing, dominant arm bound and with bilateral arm bound.

Step Length with arm swing (A)	25	35	38	36	30	33	27	28	34	34	27	31	33	47	45	36	31	40	37	47
Step length with dominant arm bound (B)	28	34	40	40	35	39	27	31	42	41	34	32	28	43	41	36	29	38	33	45
Step length with b/l arm bound (C)	24	36	35	45	31	38	53	34	44	24	26	28	26	40	39	31	27	38	30	40

Table 5: Comparison of the differences, in the stride length, while walking.

Stride length with arm swing	54	72	82	74	61	75	47	74	91	66	59	66	72	88	93	85	80	69	78	96
Stride length with dominant arm bound	55	70	80	80	61	68	48	72	86	78	60	69	54	86	85	83	72	70	76	96
Stride length with b/l arm bound	49	76	76	84	65	78	99	72	84	53	58	60	66	82	85	80	71	67	72	94

Table 6: Comparison of the differences in the step width while walking.

Step width with arm swing (G)	16	17	14	18	15	14	17	18	16	18	16	14	16	16	18	15	13	14	14	17
Step width with dominant arm bound (H)	14	17	15	15	18	16	16	16	15	17	17	17	16	17	16	15	13	13	14	17
Step width with b/l arm bound (I)	17	14	12	15	16	12	13	15	13	16	14	15	15	16	16	14	14	13	12	16

Table 7: Comparison of Cadence as per age.

No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Age	6	6	6	6	7	7	7	8	8	8	9	10	10	11	11	11	11	11	12	12
Cadence	70	90	107	100	80	81	102	91	97	115	96	118	105	118	120	108	100	102	115	117

locomotor function and neural development. The results suggest that the quantitative measures of stride dynamics may be useful in augmenting the early detection and classification of gait disorders in children [14].

Decreased performance in the initial phase of global gait stability while walking with normal arm swing may be explained in terms of increased inertia. When the hands are tied to the body, the upper body has a greater and effective inertia. This results in more resistance to perturbations. This hypothesis of greater steady-state gait stability due to greater effective inertia can be tested by subjects walking with their arms fixed away from the body. It results in restricted arm swing; while rotational inertia is further increased [10].

Restriction of arm swing also causes different (trunk) muscle activation patterns. There is scarcity of the literature reporting this effect, and it did not measure muscle activity. When a perturbation occurs to the upper body with the arms tied, the constrained upper body will tend to behave more like an inverted pendulum than the unconstrained upper body. This will be less able to recover from a perturbation. Thus the present results suggest that, from a stability point of view, until a perturbation occurs, the optimal strategy would be to walk with the hands alongside the body [7]. It is also of great consideration that, ongoing arm movements are needed to perform the rapid arm movements required for successful recovery.

Future experiments, in which the hands tied to the body and released at the instant of other perturbation, are required. In this context it should be noted that while this strategy of holding the arms alongside the body until a perturbation occurs may be optimal with respect to stability. But it is certainly not optimal in terms of energy costs. This may explain why humans do not normally walk like this. Interestingly, non-human primates displaying bipedal gait seem to be doing exactly similar, but this has never been explicitly reported. Even if this observation were to be confirmed, it remains to be investigated whether this constitutes a strategy to optimize stability [15].

The immature gait dynamics in children may reflect the subtle and ongoing development of more than one component of motor control. According to dynamic action theory, locomotor function can be viewed as a complex system with multiple degrees of freedom. The collective behavior of which is governed in part by the principle of self-organization. Therefore mature locomotion dynamics emerge only when all of the interacting individual components are fully developed. The changes in scaling exponents with age which is a measure associated with a non-equilibrium dynamical system with multiple degrees of freedom, may reflect this emergent behavior. Candidate elements that could affect stride dynamics include biomechanical and neural properties. These are known to mature only in older children e.g. electromyogram recruitment patterns are more variable in children who are <7 yr of age [4,15].

Conclusion

From the study it can be concluded that arm swing has a significant effect on the step length, stride length and step width of children in the age group of 6 to 12 years. It is seen that the step length, stride length and step width are decreased when there is no arm swing as compared to when normal arm swing is allowed. Moreover, it is observed that the step length, stride length, step width and cadence increase as the age increases in 6 to 12 years old children. Furthermore, it is seen that hand dominancy has no effect on gait in children.

Limitations of Study

- The sample size selected was small consisting of only 20 subjects.
- Unequal number of left and right handed individuals was taken.
- Chances of personal and technical error.

- More technically efficient gait analyzer can be used.

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