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Asymmetry of Step Length in Relationship to Leg Strength in 200 meters Sprint of different Performance Levels

by
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The purpose of this study was to quantify and compare asymmetry of stride length during 200 m sprint in different levels of performance. Six sprinters from national and regional levels participated in the study. They were assigned to 3 groups: school-boys (novice sprinters) junior (intermediate) and senior (advance - national and regional level) category. This study investigated selected kinematic parameters with special focus on stride length. The resulting values were measurements of each stride length (rounded-off to nearest full centimeter) during a 200 m sprint, using a manual stride measurement method. The findings indicate that the asymmetry of stride length exists in all categories, and the impact on decreasing velocities of the youngest sprinters (school-boys) are significantly associated with shorter strides, whereas cadence has little change. However, when a statistical adjustment was made for each group of runners it was found that more advanced runners did not have a significantly higher level of asymmetry with stride length at any given velocity.

Keywords: *200 m sprinting, stride length, stride asymmetry, limb preference*

Introduction

One of the most popular of all human activities is running, irrespective of speed development. The 200 meter dash is a classic sprinting event that combines excellent speed, high level of speed endurance of short duration, technique (that allows sprinters to cope with centrifugal forces when sprinting around the curve) and of course, proper strategy. All of these elements create one of the most exciting track racing events. The event draws sprinters from both the 100-meter and 400-meter dashes, so the competition tends to be diverse. It is known that the maximal velocity comes from the optimal relationship (combination) between a sprinter's stride length and stride frequency. There is a number of research projects related to the measurement of above two variables (Mann R., Herman J.1985, Susanka at al. 1989 b, Ae at al. 1992, Bruggemann at al. 1999, Ferro at al. 2001) but this paper will investigate the symmetry or asymmetry in the actions of the lower extremities during sprint running especially on the curve (200 m). This type of research has not received considerable attention, therefore, many aspects of this problem still need to be clarified. The purpose of the present study was to determine the following issues:

1. Do the lower extremities behave symmetrically or asymmetrically during 200 m sprint running (stride development)?;
2. Is the limb preference (laterality) affected by symmetrical or asymmetrical behavior of the lower extremities in stride length development?;
3. Is the limb dominance dependent upon the level of strength of their functionality?;
4. How much the symmetrical or asymmetrical behavior of the lower extremities depend on the curve radius during sprinting 200 m?

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Such variables could be important considerations of any research. This information will promote the understanding of the kinematics of the 200 m run and the importance of variability of stride length (SL). Additionally, it will provide a basis for developing specifically designed training protocols, which take into consideration running technique on the curve.

Methods and materials

The direct experiment included six male sprinters (age = 21.3 ± years, height = 179,9 ± cm weight = 74 ± kg, 100 m performance = 11,18 ± 0,17 s and the best results = 10,78 s). The data for the analysis of the 200 meter run was obtained using a simple manual stride measurement method. The passage marks were placed at each 50 m interval of the 200 m running track, which allowed interval times to be recorded at each 50m. In order to determine the stride length from the spike mark on the synthetic track (Tartan), the running shoes (spikes) were prepared with thin polyurethane foil (cream). The manual stride measurement was used because the data collections via video system were possible only for those sprinters not visually obscured or interfered with by other sprinters, as typically occurs in transition from the curve to straightaway, where the view of some sprinters were blocked by other sprinters. Therefore, the authors decided to apply an old fashion method of measurement by using special constructed devices. Each measurement was made by a 3 m long metal device placed on special ramp with a moveable mark that accurately measures distance between two footprints. In addition to the basic kinematic parameters of a 200 m run (stride length, stride frequency and time), the anthropometrics and physical ability of sprinters were also investigated. To find any conclusion and recommendation, it was necessary to vary the 200 m distance in special sections in order to estimate the proportionate changes of stride length made during right and left leg take-off,, and stride frequency and time. The investigated variables were computed by adequate statistics All subjects were pretested to determine their weight and height, leg strength, leg length, and performance time in the 100 m dash. To determine leg strength, three types of jumps were applied: standing five-jumps protocol, Sargent vertical jump protocol (jumping as high as possible and slapping the wall) and standing long jump protocol. The highest/longest jump (in centimeters) from three attempts was recorded for each test. Leg length was measured from the greater trochanter on the femur to the sole of the foot using a millimeter tape.

Results

The present study is the first to describe the stride length and leg strength characteristics of 200 m sprinters from a symmetry or asymmetry point of view. Despite limitations in the small sample size, we feel this investigation took a first step in bringing valuable information to coaches and professionals on how to succeed in sprint performance, from a stride length asymmetry perspective. The data presented shows individual and group results to help coaches assess the performance of each athlete and to allow selection of the most important variable that can improve competition strategy.

Anthropometric measurements

Each athlete's height, weight, leg length (greater trochanter to the sole of the foot) and trunk length were measured. According to collected data, we also calculated two indexes: height/weight and trunk/leg. Since no bilateral difference was found, an average value of both left and right sides was calculated for each length and circumference parameter. The subject data for the three groups is shown in Table 1. Generally, there is a lack of essential differences in anthropometric measurements between competitors. Some differences were seen in split times between the groups. Most of the sprinters are over 180 cm tall, although the differences between the tallest and the shortest is about 15 cm. A statistical association was found between the trunk length and leg length. School-boys have the same trunk length as seniors but definitely shorter legs (respectively, 8,5 cm shorter than seniors and 12 cm shorter than juniors). The differences between seniors and juniors were smaller. There is an interesting regularity connected with our results. The school-boys have better physical parameters than seniors and juniors when they where at their age, thus the age of 15 appears to be a reliable criterion in sport (athletics) selection of potentially talented athletes.

200 m sprint run characteristics

Table 2 contains the numerical characteristic of a 200 m run. There is substantial difference in race time between individual competitors. A comparison of the range of times and the running velocities be-

Table 1

Means and standard deviation of groups of selected anthropometrical measurements

Body parameters	Seniors (G1)		Juniors (G2)		School- boys (G3)		n= 6	
	x̄	σ	x̄	σ	x̄	σ	x̄	σ
Age (years)	24,0	1,41	19,0	0,0	15,0	0,0	19,3	4,08
Height (cm)	179,0	5,65	182,0	4,94	177,0	4,24	180,5	5,54
Weight (kg)	72,5	4,94	65,0	5,56	65,0	4,12	69,00	4,60
Trunk length (cm)	67,0	4,24	72,0	0,0	65,0	7,15	68,25	3,55
Leg length (cm)	89,5	4,59	93,0	2,47	81,0	11,66	92,25	6,23
Index: height/weight	0,30	0,02	0,34	0,02	0,32	0,01	0,310	0,02
Index: trunk/leg	72,2	0,98	75,98	1,97	72,66	8,55	196,1	10,13

Table 2

Numerical characteristics of groups of selected kinematic parameters measurement in 200 m run

Kinematic parameters	Seniors (G1)		Juniors (G2)		School- boys (G3)		n=6	
	KM	MK	RS	RW	MS	MZ	x̄	σ
Time (s)	21.4	22.3	21.8	22.1	25.6	25.5	23,08	1,86
Velocity (m/s)	9,34	8.96	9.17	9.05	7.81	7.84	8,69	0,68
Stride frequency (Hz)	4.30	4.17	3.99	4.07	3.79	3.96	4,05	0,18
Stride length (cm)	219.39	216.61	229.96	222.27	207.18	199.04	215,74	11,05
Number of strides	91.16	92.31	86.97	89.98	96.53	100.48	92,90	4,85
Number of strides; take off from LL (cm)	45.16	46.31	43.97	45.00	48.00	50.48	46,29	2,45
Number of strides; take off from RL (cm)	46.00	46.00	43.00	44.98	48.53	50.00	46,42	2,50
Stride length take-of from LL (cm)	221.76	219.65	232.41	225.65	206.47	201.96	217,98	11,60
Stride length take-of from RL (cm)	216.98	213.69	227.56	218.88	207.91	196.15	213,53	10,69
Difference between LL and RL	4.78	5.96	4.85	6.77	1.44	5.81	4,93	1,87
Stride index (leg length/stride length)	2.28	2.41	2.37	3.39	2.12	2.46	2,50	0,45

tween competitors, and within division of groups reveals that there were no significant differences between seniors and juniors. Significant differences were seen between those two groups (juniors and seniors) and school-boys. The difference between the fastest and the slowest sprinter was 4,2 s, however the group of juniors and seniors represented the same level (21,95 s and 21,85 s respectively). Significant differences were found between each sprinter and group for all stride length dependent variables, including number of strides and stride length at take off from the left and right leg. It is important to notice that all competitors had a longer stride with the left leg.

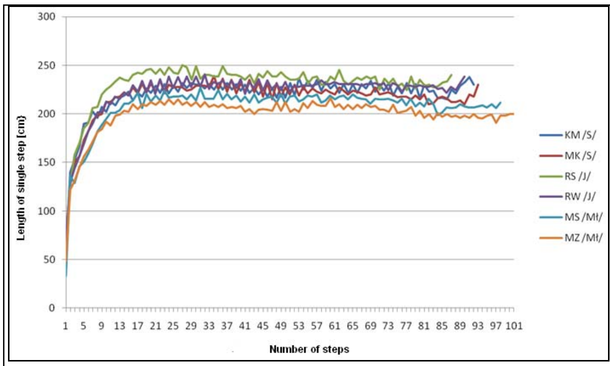

Figure 1

Trends in the in single steps length development during 200 m performance (n=6)

Stride length asymmetry

The main focus of this particular part of study was only on the dynamics of stride length curve of 200 m sprint running. To see dynamics of stride length curve (Figure 1), it is important to observe the interaction between stride length obtained at take-off from left and right leg throughout the 200 m distance, and during each of four - 50 m sections in different configurations.

As expected (Table 3), the step length increased gradually during first three 50 m sections in nearly all competitors. The pattern of increasing step lengths were similar for two groups; juniors and school-boys showed longer strides made during the second section (50-100 m of the 200 m distance), however the seniors group had the longest stride in third section (100-150 m). The same was true for the step length executed from the inside and outside leg. The step length executed from the inside leg, compared to take-off from the outside leg, was longer for most of the sprinters. Sprint values changed proportionally (increase) to that seen in regular stride patterns. The "regular stride pattern" means that the

Table 3

Numerical characteristics of groups of selected parameters of stride measurement in 200 m run divided on 4 (fifty meters) sections: 0-50 m, 50-100 m, 100-150 m, 150-200

Parameters	0-50 m		50-100 m		100-150 m		150-200 m	
	x	σ	x	σ	x	σ	x	σ
Number of strides	25,28	1,24	22,24	1,20	22,42	1,07	22,96	1,39
Number of strides: take-of from LL	12,48	0,74	11,20	0,58	11,24	0,58	11,49	0,78
Number of strides: take-of from LL	12,79	0,74	11,04	0,63	11,18	0,50	11,46	0,64
Difference between LL and RL	0,61	0,36	0,15	0,15	0,23	0,26	0,21	0,16
Stride length (cm)	198,19	9,67	225,29	11,91	223,41	10,49	218,42	12,90
Stride length take-of from LL (cm)	188,99	35,16	227,37	13,24	225,25	10,79	219,76	13,23
Stride length take-of from RL (cm)	195,12	10,68	223,96	11,26	221,87	10,49	216,98	12,81
Difference between LL and RL (cm)	7,82	3,99	5,39	1,67	3,39	3,49	3,20	2,88
Shortest stride (cm)	129,50	5,89	216,00	10,35	217,33	10,13	210,67	12,16
Longest stride (cm)	232,00	11,56	233,50	13,16	232,0	12,18	227,00	14,00
Difference between LL and RL (cm)	104,17	10,55	17,50	4,37	13,00	2,28	16,33	3,88
Longest: take-of from LL (cm)	227,17	11,60	229,33	13,72	227,33	11,98	224,50	14,86
Longest: take-of from RL (cm)	229,33	13,25	231,50	14,45	230,50	12,53	225,50	13,10
Difference between LL and RL (cm)	7,50	3,21	6,17	4,45	6,17	4,07	4,00	1,89

length of the stride attained from left and right take-off leg in few consecutive strides kept almost constant value.

The transition from curvilinear running (40-90 m section of 200 m distance) to straight running (140-190 m section of 200 m distance) was associated with significant decreases in overall step length, which was split into inside (left) and outside (right) legs ($p<0.05$). However, the mean step length executed from the outside leg (right) during running indicated there was quite significant reduction in step length compared to the inside (left) leg in all competitors. This reduced step length in all participants is probably caused by accumulated fatigue at the end of the race. The step length was significantly reduced in left leg take-off compared to the right leg in the second section (140-190 m) ($p<0.05$) during curvature motion (40-90 m). Table 4 indicates also that a similar adaptation was evident for the number of strides executed for specific sections of the race, and the pattern of the longer and shorter steps made.

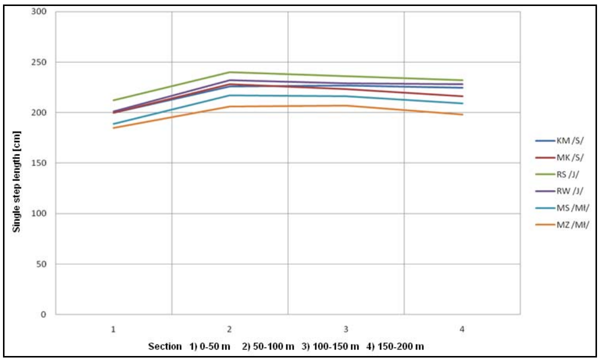

Figure 2

Comparison of average step length with division on four 50 m sections

Legs strength characteristics

The physical characteristic of leg strength (Table 5) should be analyzed from the point of view of quantity differences between averages of the three analyzed groups, and differences between competitors within the same groups, despite the low numbers of participants. Generally, one can state that school-boys are among themselves in their similar level of motor abilities regarding leg strength. Among seniors and juniors, there are differences, although specialization in the development of motor abilities and physical efficiency is more noticeable. This reflects also the dominance of one or two features of individual sprinters. The significant differences between school-boys and other groups are manifested in age and in biological development of physical features, as well as the level of sport performance.

The analysis reveled a statistically significant correlation ($p<0.05$) between some parameters. The trunk length and the height significantly influenced the number of executed steps and the step length (0.81 and 0.88, respectively). From all five physical tests which evaluate the competitors leg strength, only two--double legs vertical jump and single left leg vertical jump--were positively correlated with stride length, showing correlations of 0.88 and 0.83,

Table 4

Numerical characteristics of groups of selected parameters of stride measurement in 200 m run divided on 2 (fifty meters) sections: 40-90 m, 140-190 m

Parameters	40-90 m		140-190 m	
	x	σ	x	σ
Number of strides	22,18	1,19	22,88	1,34
Number of strides: take-of from LL	11,23	0,57	11,49	0,65
Number of strides: take-of from LL	10,94	0,66	11,39	0,71
Difference between LL and RL	0,33	0,27	0,24	0,10
Stride length (cm)	226,31	12,53	219,10	12,43
Stride length take-of from LL (cm)	228,91	12,39	220,35	13,24
Stride length take-of from RL (cm)	223,08	11,68	217,84	11,88
Difference between LL and RL (cm)	5,83	2,13	3,25	3,23
Shortest stride (cm)	218,33	11,62	211,50	12,53
Longest stride (cm)	234,00	12,198	227,83	13,50
Difference between LL and RL (cm)	15,67	3,08	16,33	3,78
Longest: take-of from LL (cm)	225,33	13,99	216,17	17,72
Longest: take-of from RL (cm)	231,83	12,81	227,17	12,98
Difference between LL and RL (cm)	10,83	7,08	12,33	7,94

Table 5

Numerical characteristics of groups of selected leg strength dynamic measurements

Parameters	$\overline{x}$	min.	max	SD
Standing five jumps (m)	14,09	12,30	15,90	1,56
Double legs vertical jump (cm)	59,18	45,10	68,00	9,25
Single LL vertical jump (cm)	48,70	33,30	58,70	11,20
Single LR vertical jump (cm)	42,42	27,30	54,70	11,24
Standing long jump (cm)	2,71	2,23	3,05	0,37

respectively; while the number of executed strides were negatively correlated at -0.88 and -0.83, respectively). An interesting fact involved the lack of correlated strength significance seen with single right leg vertical jump,, as compared to the significance seen with the left leg. The analyses also showed that the leg length did not correlate with stride length, as the authors expected.

Discussion

The result of the experiment show that the differences in the development of the step length during 200 m performance are evident for sprinters in all three groups. This can be seen particularly when the distance is divided into four 50 m sections. Analysis of changes in stride length and comparison to selected leg strength measurements also reveals that the development of stride length with a division on the step length executed from left (inside) leg and right (outside) during the 200 m run. The analysis of the changes in step length executed both from left leg and right leg showed close relationship with the selected tests that measure leg strength. It reveals

Table 6

Correlation between selected step length and other variables

Parameters	**Number of steps**	**Step length**	**Step length take off from LL**	**Step length take off from RL**
200 m time (s)	0,77	-0,77	-0,77	-0,77
Leg length (cm)	-0,37	0,37	0,37	0,37
Trunk length (cm)h	**-0,81**	**0,81**	**0,81**	**0,81**
Height (cm)	**-0,88**	**0,88**	**0,88**	**0,88**
Body mass (kg)	-0,44	0,43	0,43	0,43
Standing five jumps (m)	-0,60	0,60	0,60	0,60
Double legs vertical jump (cm)	**-0,88**	**0,88**	**0,88**	**0,88**
Single LL vertical jump (cm)	**-0,83**	**0,83**	**0,83**	**0,83**
Single LR vertical jump (cm)	-0,77	0,77	0,77	0,77
Standing long jump (cm)	-0,77	0,77	0,77	0,77

that the development of optimal stride length with special attention to the curve is more complex than we think and required appropriate training application (Deriex 1991).

In this article we have used the term "step" to define half a running cycle, that is, from foot contact to the next contact of the opposite foot. The term "stride," therefore, defines a complete cycle, from foot contact to the next contact of the same foot. The optimal relationship between those two factors for an individual athlete depends on his standing height, leg length, crular index, explosiveness of muscular contractions, speed of movement of the limb and range of motion in the main joints (Kuntz and Kufman, 1981; Donati, 1995; Cavanagh and Kram, 1989).

The studies done by Lopez (1981) and Bosko and Vittori (1986) revealed that step frequency is primarily determined by genetics, while step length could be improved by application of special strength exercises, including: weight exercises, skipping and bounding drills, and uphill running. However, there is a large dispersity of scientific opinions regarding the significance of somatic variables in sprint running. Iskra (2001) showed that anthropometric variables do not correlate directly with running speed, but may be in close relation with stride length.

The asymmetrical behavior of the lower limbs expressed by differences in step length during walking and running probably reflects the natural functional differences between the lower extremities (Sadeghi, Allard, Prince and Labelle ((2000). Extensive research done by Hirasawa (1982, 1984) confirmed that one lower limb is mainly responsible for support and body weight transfer during walking while the contralateral limb contributes more to propulsion. We can suppose that this same function of the lower limb translates into sprinting. Therefore, the existence of asymmetry between step length can be partially explain on these observations. Arguably, the inside leg (left) is likely responsible for a stronger take-off, and thereby a longer step, thus contributing more (than right leg) to forward propulsion.

In current discussion regarding step symmetry or asymmetry in walking and running, the limb preference and laterality has been cited as an explanation for the existence of functional differences between the lower extremities (Peters, 1983; Gabbard, 1996, 1997; Devita et al., 1991)

Our studies supported this hypothesis, which claimed that the dominant limb compensates better for longer step. The longer step was executed from the preferred, or dominant, leg. In most cases the left leg showed the dominance. However, Devita (1991) and his colleagues documented that the dominant limb was the right leg, which was responsible for their subjects generateing between 56-61% of total positive work during walking at natural speed. According to Gabbard and Hart (1996), the limb dominance is related to the notion that the two hemispheres of the human brain are functionally dissimilar. The leg strength experiment acknowledged the preference of left lower extremity (higher jump) during single leg vertical jump and leg placement in block start (left leg in front). However, further investigation is needed for asymmetry and speed of movement comparisons, as well as between dominant leg and functionality of stride asymmetry and its relationship to laterality.

It is not surprising that no significant bilateral difference was found in leg strength parameters and their influence on the asymmetrical behavior of the lower extremities (step length). It is a result of the nature of sprinting, where a sprinter should put similar stress of both legs. Significant differences can appear when considering movement patterns (straight path running and curve path running, such as during a 200 m sprint). During the sprint, our subjects displayed substantial asymmetry in step length. The leg strength measured by vertical jump from double leg take-off and vertical jump from single leg take-off (left) indicated significant correlation with step length r=0.88 and 0.83, respectively ($p \leq 0.05$).

There were a few studies of curved path sprinting and maneuverability during controlled conditions (Walter, 2003; Usherwood and Wilson, 2005) and running technique Harrison and Rayan 2000. Maximum sprint velocity as a function of the radius for normal curve running (open circles) and tethered running (filled circles) have decreased with decreasing radius (Greene, 1985).

According to Chang and Kram (2007), during curve sprinting, the inside leg consistently generated smaller peak forces compared to the outside leg. Smaller peak forces results in less power ($P(t) = \mathbf{F}(t) \cdot \mathbf{v}(t)$).during take-off and automatically a shorter step. Chang and Kram (2007) claim that several biomechanical limitations placed on the stance leg during curve sprinting probably make the inside leg more ineffective at generating ground reaction forces . These forces are necessary to achieve

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maximum velocities comparable to straight path sprinting. This statement proves that higher velocities are reached on the straight path, than on the curve. This experiment, however, did not specify the differences between stride lengths on the straightaway or on the curved path

The findings of this study indicate that asymmetry of step length during 200 m sprinting are unique and quite consistent among all subjects. In addition, better runners, based on performance level and time during the experiment, were no more symmetrical than those with slower race times (school-boys). The fastest sprinters (seniors) exhibited near symmetry (equal step length from left and right take-off leg) in some parts of the 200 m running distance. (50-60 m (K.M., M.K,), 80-90 m (K.M.), 140-150 m (M.K.), 170-180 m (K.M., M.K.)

Conclusion

1. The length of steps during 200 m performance in all participants (n=6) indicated length asymmetry exists; thus, longer steps were executed at take-off from left lower extremity (inside leg).
2. The investigation did not clearly demonstrate an influence of lower limb preference (laterality) on step length, however, all subjects (n=6) acknowledged the preference (higher jump) of left lower extremity during single leg vertical jump and leg placement in block start (left leg in the front).
3. Leg strength measured by vertical jump from a double leg take-off and a vertical jump from single leg take-off (left) indicated a significant correlation with s stride length r = 0.88 and 0.83, respectively ($p \leq 0.05$). However, due to a small sample size (n=6) and high diversity between participants, single measurements of leg strength did not significantly affect the correlation coefficient values for stride length. The single functionality of the lower extremities was also not clearly defined. Further investigations into the kinetics of lower extremities during sprint on the curve is required.The experiment found a direct impact of the curve radius (track lane number) during sprinting 200 m on the stride length from left or right leg take-off, however the authors suppose that the level of technical proficiency and the value of running velocity can determine the behavior of the centrifugal force and its impact on the stride length. Similar to point 3, this requires additional investigation.

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